Municipal Bond Insurance and the U.S. Drinking Water Crisis*

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Abstract

The alarming rise in drinking water pollution across the U.S. is often attributed to cost cutting pressures faced by local officials. We know little, however, about why these pressures are so severe for some cities compared to others. We present a new theory to argue that an important contributor to recent drinking water emergencies is the collapse of the municipal bond insurance industry. Public water infrastructure has traditionally been financed using municipal debt partly backed by a small number of monoline insurers. Starting in the 90's, some of these insurers became increasingly involved with structured financial products unrelated to municipal water bonds, such as residential mortgage backed securities. We show that when these products crashed in value in 2007, municipalities that had relied more heavily on these insurers for water infrastructure financing subsequently faced higher borrowing costs. These municipalities then reduced their borrowing and scaled back investments in water infrastructure, which in turn, has led to elevated levels of water contamination. Our findings thus reveal how the U.S drinking water crisis can be partly traced back to financial market failures.

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1 Introduction

The U.S is currently in the midst of a public drinking water crisis (Allaire et al., 2018). Over the past 15 years, cities such as Pittsburgh, Newark, and Detroit have experienced elevated levels of drinking water pollution. Residents in Flint, Michigan continue to depend on government-provided bottled water to this day—six years after contaminants such as lead, trihalomethanes (TTHM), and E. Coli were first reported in its water. A common explanation for these episodes is that local officials, faced with tight budgets and cost cutting pressures, have turned to inexpensive water delivery methods that are subject to high environmental failure rates (American Society of Civil Engineers, 2017).

What is less understood, however, are the root causes for why the financial pressures in some cities—but not others—are so severe that they lead to drinking water emergencies. Tight budgets, after all, are a constant problem for government officials at all levels. And yet, some cities are able to withstand these pressures and provide safe drinking water, while other cities are unable to stem their descent into public health crises.

In this paper, we argue that an important, but overlooked, contributor to the U.S. drinking water crisis has been the collapse of the municipal bond insurance industry. Historically, municipal governments relied heavily on bond insurance when issuing debt to finance investment into drinking water infrastructure. The insurers that provided this insurance were rated AAA for decades, and were responsible for any debt repayment shortfalls due to municipal default. Starting in the 1990's, several prominent insurers began to insure structured financial products unrelated to drinking water bonds, such as residential mortgage backed securities (RMBS) (Drake and Neale, 2011). When these products unexpectedly crashed in value in 2007, these companies were faced with massive insurance claims, causing their credit quality to plummet (Moldogaziev, 2013; Cornaggia et al., 2020a).

We propose and test the hypothesis that these credit events started a chain reaction that has led to increased drinking water pollution across the U.S. Specifically, we argue that municipalities that had historically relied on bond insurance companies whose ratings unexpectedly crashed in 2007, suffered higher costs of municipal debt financing—even as these municipalities remained solvent. In turn, we hypothesize that municipalities affected by these shocks raised less external financing and cut back on investment in public water infrastructure, which has subsequently led to increased levels of drinking water pollution.

Underlying our hypothesis is a model in which municipal bond insurance serves to ease financing constraints faced by local governments. An important friction that is commonly used to describe municipal bond markets is asymmetric information between issuers and investors. U.S. municipalities are often branded as opaque because they do not face the same disclosure requirements as public corporations (Aguilar, 2015). To overcome this opacity, bond insurance can serve as a signalling device that enables municipal governments to convey their credit-worthiness to otherwise uninformed investors (Thakor, 1982).

We hypothesize that negative shocks to bond insurance companies exacerbate financing frictions faced by local governments. If insurers become unable to service their insured debt obligations in case of municipal default, municipalities effectively incur a reduction in the pledgeable income available for them to attract external financing. We predict that municipalities respond to higher external financing costs by raising less debt and reducing infrastructure investment, which in turn leads to higher levels of drinking water pollution.

The null hypothesis that we contrast is the view that credit events in the bond insurance industry do not have a material impact on drinking water quality. This view is theoretically compelling for several reasons, and may explain why the link between bond insurance and drinking water emergencies has not been established previously. First, the municipal bond market may largely be frictionless in practice, if municipalities are able to use alternative tools such as credit ratings and voluntary disclosures to overcome adverse selection. Second, municipal default is historically rare, so insurer credit rating downgrades may have no empirically detectable impact on municipal borrowing costs. Third, local officials may respond to potential insurance holdups by raising capital from other sources, such as tax revenues, service fees, and even other viable insurers, in order to overcome any shortfall in debt financing due to insurance unavailability. Fourth, local government officials may have different objective functions from corporate managers: government officials may be willing to provide public goods such as clean drinking water even when it is "unprofitable" to do so.

To test our hypothesis, we construct a new dataset that links municipal balance sheets with bond insurer characteristics and measures of public drinking water quality. The data enable us to examine cross-sectional and time-series variation in municipal finances, and examine how municipal financing and investment behavior change in response to monoline insurer credit events. In particular, we devise an identification strategy that exploits institutional characteristics of the bond insurance industry, to estimate the causal impact of bond insurer credit quality on municipal borrowing and infrastructure investment.

Prior to 2007, all insurers had AAA ratings, and municipalities would often use multiple insurers to insure their debts. Starting in 2007, however, nine out of the eleven largest bond insurers in the U.S. experience an unexpected deterioration in their credit quality and/or stop insuring new municipal debt, due to their exposure to securitized loan defaults (Cornaggia et al., 2020a). Assured Guaranty Corp. and Financial Security Assurance are the lone exceptions; they had not invested significantly in structured debt products, which enabled them to maintain high credit ratings and continue to insure municipal debt even after 2007 (Moldogaziev, 2013).

We compare municipalities that have high versus low exposures to downgraded insurance companies, based on the amount of municipal debt that is insured by these firms in 2006 (while keeping the total amount of insured debt across municipalities fixed). We posit that municipalities that have relatively high (i.e. above sample-median) fractions of municipal debt backed by downgraded insurance companies experience a more severe shock to financing constraints than municipalities with relatively low (i.e. below sample-median) fractions of debt insured by downgraded insurers. The key identification assumption is that the credit rating downgrades of specific bond insurers are unanticipated and exogenous to pre-crisis heterogeneity in bond insurance usage across municipalities. As discussed later, we offer numerous empirical and anecdotal evidence to support the validity of—and reject potential violations of—this identification assumption.

To illustrate our identification strategy, it is helpful to consider a case study of two municipalities in our sample. Saline and Geary counties in Kansas both have approximately 68% of their outstanding municipal water debt insured by monoline insurers as of 2006; they both issue debt at an offering yield of 6%. However, while all of Geary county's insured debt is backed by MBIA, Saline County's debt is backed by two companies: 48% by MBIA and 20% by FSA. In our sample, the median fraction of municipal debt insured by insurers that experience ratings downgrades (which includes MBIA, but not FSA) is 53%. We thus assign Geary county to our "treatment" group, and we assign Saline county to our "control" group.

Applying this strategy to all municipalities in our sample, we present a number of new empirical findings that support our hypothesis and reject the null. First, we document the historical importance of bond insurance for municipal financing, and illustrate the empirical relevance of bond insurer downgrades during the crisis. In 1980, the total debt raised by local municipalities for water infrastructure was $2,422 million; 7.33% of this debt was insured. In 2007, the total debt raised by local municipalities for water infrastructure was $26,190 million; 47.5% of this debt was insured. In 2008, however, although $24,596 million in municipal debt was raised for water infrastructure, the fraction of this debt that was insured was only 21.5%; the percentage of insured debt further decreased to 8.93% in 2011. The dramatic rise and fall of the bond insurance industry thus appears to be an empirically salient feature of the municipal bond market.

Second, we show that treated municipalities that had historically relied more heavily on insurers that later receive negative shocks in 2007, subsequently suffer higher costs of external debt financing than municipalities that were historically less reliant on downgraded insurers. Our analysis shows that yields on bonds offered by treated municipalities increase by 14 basis points relative to bonds issued by municipalities in the control group. Consistent with our hypothesis, the data indicate that treated municipalities face higher borrowing costs due to credit events in the bond insurance industry, even when those municipalities remain solvent.

Third, to verify that treated municipalities' actually pay higher borrowing costs—as opposed to face higher costs that they do not pay—we analyze Census data on municipalities' actual debt servicing costs. We observe that treated municipalities do indeed pay approximately 10% higher debt servicing fees following the negative shocks to monoline insurers. These findings suggest that treated municipalities incur greater costs of debt servicing following insurer rating downgrades, likely reflecting not only the higher costs of new debt financing, but also relatively less favorable terms of refinancing on existing debt.

Fourth, we show that treated municipalities reduce their revenue debt relative to municipalities in the control group. After 2007, treated municipalities reduce their debt issuance by at least 2% (of their outstanding revenue debt) relative to control municipalities. The data therefore show that municipalities respond to higher borrowing costs by raising less external financing, and that the deterioration of insurers' credit quality effectively restricts municipalities' access to credit.

Fifth, we show that treated municipalities reduce investment into public drinking water infrastructure (relative to control municipalities), following the negative shocks to bond insurers in 2007. The data suggest that treated municipalities spend approximately 3-4% less on capital outlays aimed at maintaining and improving drinking water infrastructure (this includes the servicing of pipes, upkeeping of supply stations and water treatment facilities, etc.). The evidence is consistent with our hypothesis that increases in municipal borrowing costs, triggered by the collapse of the bond insurance industry, lead to lower investment in public drinking water infrastructure.

Sixth, we show that treated municipalities' reductions in water infrastructure investment are associated with subsequent increases in drinking water pollution. We analyze U.S. Environmental Protection Agency (EPA) data on federal violations of water contaminant levels for pollutants such as lead, coliform bacteria, and treatment by-products. We estimate that treated municipalities that rely on downgraded bond insurers experience a 6% increase in violations of federal drinking water standards (i.e. country-wide regulations set by the U.S. Safe Drinking Water Act). These findings are consistent with the view that the observed reductions in water infrastructure investments triggered by negative shocks to insurers have real effects on drinking water quality.

We perform back-of-the envelope calculations to illustrate the broader economic magnitudes of our regression estimates. As a result of the collapse of the bond insurance industry, the municipalities in our sample face a 14 basis point increase in average borrowing costs per year, they pay $135 million more in annual interest expenses, and they reduce their external borrowing annually by $1,499 million in aggregate. Our estimates indicate that these changes lead to reductions in infrastructure investment of approximately $274 million annually, which in turn, leads to 458,433 more people being exposed to an additional drinking water health violation each year.

We perform a number of analyses to critically evaluate alternative explanations for the findings. One alternative explanation is that treated municipalities experienced a greater deterioration of general economic conditions than control municipalities during the financial crisis. Insurers that invested in structured financial products could have been more likely to insure bonds issued by municipalities that later suffered a greater decline during the crisis. This alternative hypothesis can be formulated as an omitted factor in our regression analysis.

We present evidence that our documented links between municipal outcomes and bond insurer downgrades cannot be fully attributed to changes in general economic conditions.

We show, for example, that treatment and control municipalities have remarkably similar economic characteristics before the crisis. Municipalities across the treatment and control samples serve populations of comparable size, they generate similar water service fees, and they share a similar reliance on external debt financing.

Moreover, there is little evidence to suggest that municipalities associated with particular insurers are headed in different directions prior to the crisis. Time-series trends in borrowing costs, investment behavior, and water quality are statistically indistinguishable between the two groups of municipalities prior to the crisis. If anything, there is some evidence to suggest that treated municipalities actually had *higher* quality drinking water than control municipalities prior to 2007.

Even after the 2007 insurer credit events, treatment and control municipalities do not show significant differences in population growth or property tax revenues—proxies for general economic conditions that might otherwise explain disparities in municipal outcomes. We also show that there are no significant differences in drinking water revenues in the immediate years following the crisis. These findings suggest that there are no demand-side reductions in municipalities' pledgeable income sources that might otherwise explain increased borrowing costs for drinking water infrastructure bonds.

We also note that our results on borrowing costs and borrowing amounts are driven by revenue bonds, rather than general obligation bonds. In fact, 86% of the debt in our main sample corresponds to revenue bonds. Revenue bonds are securities that are raised specifically for drinking water infrastructure investments; repayments for these bonds are restricted to the cash flows generated by these projects. In contrast, general obligation (G.O.) bonds are securities whose debt servicing costs can be sourced from any income streams available to a municipality, including service fees for projects that exist outside of water infrastructure.

If treatment and control municipalities experience differential trends in general economic conditions after 2007, we should observe our main results for G.O. bonds, rather than revenue bonds alone, because the income streams tied to G.O. bonds will be more reflective of general economic conditions than the income streams tied to revenue bonds. Our results to the contrary, however, suggest that our results are best explained by our main hypothesis, rather than an alternative explanation centered around divergent economic conditions across municipalities.

In our final analysis, we present suggestive evidence that sheds light on the specific frictions that underlie our results. Our main findings are consistent with bond insurance serving as a signalling device that municipalities use to overcome adverse selection. Thakor (1982) further suggests that a negative shock to bond insurance will be especially relevant for high quality municipalities who purchase costly insurance to signal their quality to uninformed investors. We support this view by showing that our results are stronger for higher quality municipalities, where quality is (coarsely) proxied by property tax revenues per capita.

Other frictions that have been cited as motivations for bond insurance appear less relevant to our empirical results. For example, Nanda and Singh (2004) argues that municipal bond insurance exists as a means of preserving the tax-exempt status of municipal payouts during default. Their paper suggests that a negative shock to bond insurance should be particularly relevant to bonds of longer maturity. We find mixed evidence supporting this prediction.

Another mechanism that we consider centers around potential changes in investor demand for municipal debt. Some studies suggest that negative shocks to bond insurers might reduce demand for municipal debt, by lowering the credit ratings of insured municipal bonds (Cornaggia et al., 2020b). Changes in investor demand for municipal bonds may reflect credit-ratings based regulatory constraints (Becker and Ivashina, 2015; Chen et al., 2014; Calabria and Ekins, 2013; Ellul et al., 2011; Stanton and Wallace, 2017), window-dressing objectives (Lakonishok et al., 1991), or retail investor responses to bond ratings (Cornaggia et al., 2018; Adelino et al., 2017). The results in Bergstresser et al. (2010), however, show that municipal investors who face such as incentives, such as mutual funds and insurance companies, do not significantly reduce their holdings of insured municipal debt after 2007. These findings suggest that changes in investor bond demand in response to bond insurer credit events are unlikely to explain our results.

The main contribution of this paper is empirical evidence that the recent collapse of the municipal bond insurance industry is a leading cause of the current U.S. drinking water crisis. The findings support the hypothesis that negative shocks to municipal bond insurers exacerbate financing frictions faced by municipalities, even when municipalities remain solvent. More broadly, the findings illustrate the importance of financial market imperfections in explaining public good provision. While theories of insurance and financing constraints have traditionally been examined in the context of private corporations and households, the evidence in this paper suggests that these theories are also relevant in the context of local government financing and investment decisions.

The remainder of this paper is as follows. Section 2 describes the institutional background and theoretical framework. Section 3 details the data. Section 5 contains the empirical analysis. Section 6 concludes.

2 Theoretical Framework

2.1 Institutional Background

Public drinking water in the U.S. is provided through a combination of local and federal government efforts. Water infrastructure is financed and maintained by municipal governments, who work in partnership with public and/or private water authorities. The health standards that local water systems must satisfy are governed at the federal level by the 1974 Safe Drinking Water Act (SDWA). The SDWA specifies the list of contaminants that are allowed in community drinking water systems, along with continuously updated figures on the maximum permitted levels of these contaminants. In recent work, Behrer et al. (Forthcoming) present empirical evidence that the SDWA has had a significantly positive impact on water quality.

Despite federal water regulations being in place since 1974, however, a number of studies find that violations of national health standards are on the rise in many cities. In 2015, nearly 21 million people who relied on community water systems for their drinking water were exposed to contaminants such as lead and E. Coli (Allaire et al., 2018). These pollutants have been known to cause significant long-term damage to both infants and adults, and have spurred many to claim that the U.S. is currently in the midst of a drinking water crisis (Snider, 2017; Rihl, 2020). Residents in Flint, Michigan, for example, continue to depend on government-provided bottled water to this day—six years after its drinking water was found to be contaminated with hazardous substances.

Local municipalities finance drinking water infrastructure using a combination of external debt raised from financial markets, tax revenues, and service fees. The two types of municipal bonds issued by local governments for public investments are revenue bonds and general obligation bonds. Revenue bonds are securities raised for specific purposes; the interest and principal payments for these bonds must be made from income streams tied to the specific projects that the bonds are used to finance. General obligation bonds, in contrast, are sources of financing that can be used by municipalities at their discretion for a variety of purposes; repayments of these bonds can be sourced from income streams available to municipalities without being tied to a specific project.

When issuing municipal bonds, local governments often seek bond insurance. Municipal bond insurance is a form of credit enhancement where an insurance company commits to paying any shortfall in interest and principal owed on a municipal bond in case of municipal default. Municipal bond insurers are monoline insurers by law; they are disallowed from selling insurance for non-financial assets, such as life, property, and casualty insurance. The first municipal bond insurer in the U.S. was American Municipal Bond Assurance Corporation (AMBAC), which began insuring long-term municipal bonds in 1971. Since then, municipal bond insurance grew significantly. In 1980, we estimate that the total debt raised by local municipalities for water infrastructure was $2,422 million; 7.33% of this debt was insured. In 2007, the total debt raised by local municipalities for water infrastructure was $26,190 million; 47.5% of this debt was insured.

U.S. municipal bonds are insured by a small number of monoline insurance firms. As of 2006, we estimate that 11 bond insurance companies insured approximately 98% of all U.S. municipal water infrastructure debt; more than 90% of this debt was insured by just four insurers: Financial Security Assurance (FSA), Municipal Bond Insurance Association (MBIA), Financial Guaranty Insurance Company (FGIC), and AMBAC. For many years, bond insurers uniformly maintained high credit ratings of nearly AAA. These high ratings helped municipalities raise debt with lower yields, because the credit ratings of individual issues would be the higher of either the municipalities' underlying credit rating or the monoline insurance company's credit rating (Cornaggia et al., 2020b).

Starting the 1980's, several bond insurance companies began to offer insurance for products outside of the municipal debt market. In particular, these insurers became involved in structured financial products related to the real estate market, such as residential mortgage backed securities and collateralized debt obligations backed by residential subprime mortgages (Drake and Neale, 2011; Moldogaziev, 2013). Insurer involvement in these lines of businesses accelerated in the late 1990's through the 2000's.[1] As a result, monoline insurers backed approximately $3.3 trillion in total outstanding paper across all financial products in 2006 (The Economist, 2007).

Starting in 2007, however, the wave of defaults in the residential loan market triggered billions of dollars in claims for monoline insurance firms. These events caused 9 out of the

[1] See Acharya and Naqvi (2019) for a model of intermediaries "reaching for yield" by investing in risky assets.

aforementioned 11 municipal bond insurers to experience credit ratings downgrades from investment-grade to non-investment grade. For example, FGIC's rating went from AAA to CC as a result of their structured product obligations (Richard, 2010). The exceptions to these patterns were FSA and Assured Guaranty Corporation; they had relatively limited exposure to the structured financial products that had overwhelmed their competitors. These two firms (which later merged) were able to maintain their credit-worthiness through the financial crisis (Moldogaziev, 2013).

The consequences of these events for municipal borrowing were dramatic, as downgraded monoline insurance companies stopped insuring new municipal debt issues. As shown in Figure 1 for example, in 2008, we estimate that $24,596 million in municipal debt was raised for water infrastructure, but the fraction of this debt that was insured was only 21.5%. The percentage of newly issued municipal debt that was insured further decreased to 8.93% in 2011. While there has been some growth in municipal insurance in recent years, the volume of insured municipal debt is far below its peak in the early 2000's.

2.2 Hypothesis

In this paper, we argue that one of the root causes of the U.S. drinking water crisis can be traced back to the collapse of the municipal bond insurance industry. We hypothesize that the 2007 mortgage default crisis hampered several bond insurers' ability to meet their existing municipal debt insurance obligations, which then raised municipalities' borrowing costs for new capital. In turn, these events caused municipalities to raise less external financing, cut back on investment in water infrastructure, and experience higher levels of drinking water pollution. In this section, we formulate this hypothesis in more detail and derive its empirical predictions.

The municipal bond market is considered opaque by many observers; unlike public corporations, municipalities are not subject to federal disclosure requirements when raising external capital (Aguilar, 2015). Legislative reforms to improve municipal transparency are an active debate among policymakers, partly because many pre-existing tools thought to mitigate information frictions appear to work poorly in practice (see U.S. House of Rep. Committee of Financial Services No. 110-99, 2008). For example, although credit rating agencies in theory provide valuable information about issuer credit quality to investors, a large empirical literature finds that problems such as misaligned incentives, information staleness, and regulatory capture limit the usefulness of municipal credit ratings (see Cornaggia et al. (2018) for an overview of this literature).

Bond insurance is a tool thought to help municipalities overcome information frictions when raising external capital. Thakor (1982) presents a theoretical model of how municipalities purchase bond insurance as a means of signalling their credit quality to otherwise uninformed investors. In the model, municipalities of high unobserved credit quality face a lower cost of purchasing bond insurance than municipalities of low unobserved credit quality. This assumption is consistent with the industry practice of bond insurers performing due diligence and charging municipalities with insurance premiums that reflect municipal default risk. High quality municipalities demand bond insurance because the cost of the up-front insurance premiums is more than compensated for by the benefits of lower yields that investors accept for insured bonds. In other words, bond insurance enables municipalities to borrow more capital at a lower cost than they would otherwise be able to borrow in the absence of bond insurance. This perspective is supported empirically by academic research (Gao and Murphy (2019) and Cornaggia et al. (2018)) and practitioner views.

Accordingly, we posit that a negative shock to bond insurers' balance sheets raises the cost of external financing for municipalities. Specifically, if a municipality's existing bond insurers become suddenly less able to meet their insured debt obligations, then the municipality effectively bears a greater burden of repaying creditors in case of municipal default. New potential creditors would view such a shock as a reduction in their ability to receive their interest payments from the municipality, and would thus charge a higher rate of interest to compensate for this increased risk of non-payment (assuming that new creditors are pari-passu with existing creditors).[2]

In our context, the financial crisis of 2007 constitutes an unexpected negative shock to municipal bond insurers. Several of the largest bond insurers who were exposed to structured financial products tied to real estate, faced a massive wave of insurance obligations when these products crashed in value. As a result, the crisis triggered a precipitous drop in the credit ratings of these companies, and they effectively ceased to offer insurance for new municipal debt issuances. [3]

Empirically, these events have implications for municipalities that we derive and test.

Prediction 1. *Municipalities that have greater exposure to downgraded bond insurers, face higher borrowing costs following the crisis.*

This prediction reflects the reasoning that once a municipality's existing bond insurers become less able to meet their debt repayment obligations in case of municipal default, new creditors will charge higher interest rates to compensate for the increased risk of non-payment.

Prediction 2. *Municipalities will respond to higher borrowing costs by raising less debt.*

We assume that municipalities are constrained in their ability to raise water service fees and draw from other sources of revenues that could be used to pay interest on any new debt financing. This assumption reflects a key institutional feature of municipal debt: 86% of the debt raised by sample municipalities for drinking water infrastructure are in the form of revenue bonds, which can only be repaid using cash flows generated by drinking water

[2]In the case of pari-passu debt, all municipal funds available for debt repayment must be shared equally across all creditors.

[3]The evidence suggests that municipalities were unable to find readily available substitutes for these bond insurers in the wake of the 2007 crisis. This finding is unsurprising, given that bond insurance requires due diligence and significant capital—inputs that are hard to come by during the financial crisis.

projects. The assumption is also supported by evidence that public pressure and state laws often constrain utility price setting. Thus, the first two predictions of our hypothesis imply that the negative shock to bond insurers triggered by the financial crisis represents a supply-side shock to municipal access to credit.

Prediction 3. *The third prediction of our hypothesis is that municipalities respond to higher borrowing costs by cutting investment into public drinking water infrastructure.*

Again, because municipalities are constrained in their ability to raise water service revenues, and because they have limited ability to redirect capital from other projects to pay back revenue bonds, an increase in the cost of capital for water-related debt has a binding effect on investment behavior. We implicitly assume that government officials are responsive to changes in municipal financing constraints in a manner that mirrors corporate executives who face financing constraints when raising capital for firm investment (see for example Fazzari et al. (1988)).

Prediction 4. *The fourth prediction of our hypothesis is that reductions in drinking water infrastructure investment will lead to increased levels of drinking water pollution.*

These effects could materialize in both the short-run and long-run. Constraints on investment might preclude municipalities from effectively dealing with short-run, exogenous increases in water pollution. Constraints on investment may also lead to a deterioration of water quality that is observed in the long-run (for example, through the gradual erosion of water pipes, less frequent testing of water contamination, etc.).

Our hypothesis is novel because the link between municipal bond insurance and water pollution has not been established previously. The U.S. drinking water crisis is typically attributed to aging infrastructure and insufficient tax revenues nationwide. Our theory complements these explanations by providing a rationale for why we observe a rise in drinking water pollution in some cities but not others. We argue that an additional, important contributor to the drinking water crisis has been financial market frictions exacerbated by the real estate crash of 2007.

The null hypothesis that we reject is the view that municipal bond insurance has no relation to drinking water quality. This view is theoretically compelling for several reasons, and may explain why the connection between bond insurance and water pollution has not been studied previously. For example, if municipal bond markets are largely frictionless, then shocks to municipal bond insurance will not matter for municipal borrowing costs or investment activities.[4]

Other theories of municipal bond insurance center around frictions related to investor tax preferences, regulatory constraints, and behavioral biases. For example, Nanda and Singh (2004) argue that municipal bond insurance exists as a means of preserving the tax-exempt status of municipal payouts during default. As another example, some studies suggest that negative shocks to bond insurers reduce investor demand for municipal debt, by lowering the credit ratings of insured municipal bonds. These changes may stem from credit-ratings based regulatory constraints (Becker and Ivashina, 2015; Chen et al., 2014; Calabria and Ekins, 2013; Ellul et al., 2011; Stanton and Wallace, 2017), window-dressing objectives (Lakonishok et al., 1991), or retail investor responses to bond ratings (Cornaggia et al., 2018; Adelino et al., 2017). In our empirical analysis, we consider these alternative theories and assess the extent to which they may also explain the statistical findings that we document.

[4]More generally, if capital markets are frictionless, then bond insurance adds little real value. Bond insurance claims would represent nothing more than state-contingent payments that can be replicated by investors and issuers on their own.

3 Data

3.1 Sources

We construct a unique panel dataset from several different data sources. In this section, we summarize the dataset assembly; we provide further details in the Appendix. First, we obtain data from the U.S. Census Annual Survey of State and Local Government Finances from 1980 to 2019. These data contain detailed information on the finances and investment activities of local U.S. municipalities.

In particular, the data contain records of municipal investments in drinking water infrastructure, sources of financing and associated expenses, and water service revenues. Each annual survey corresponds to a large, randomized sample of local municipalities. Additionally, every five years, the Census gathers data for the entire population of local municipalities in the U.S.

We supplement these data with information on the credit ratings of municipalities. Specifically, we obtain detailed time-series data on the credit ratings (by Moody's) of municipal entities from Eikon. We codify the credit ratings (such as Aaa, Aa1, etc.) numerically by assigning each credit rating a value, such that Aaa=21, Aa1=20...C=1, following Cornaggia et al. (2018). If a municipality does not have a credit rating, we leave this value as 'missing'.

Second, we collect detailed information on municipal debt issues from SDC Platinum's Global Public Finance database. These data contain records for every individual debt offering made by U.S. municipalities from 1966 to 2019. For each debt issue, we are able to observe the total amount raised, the debt's maturity, coupon rates, debt type (revenue bond or general obligation bond), and the stated purpose of the debt issue (for example, for water infrastructure). These data enable us to construct a detailed time-series of debt used to finance public drinking water infrastructure for each municipality in our sample.

SDC also contains information about whether an individual bond issue is insured, and if so, the identity of the insurance company that is backing the debt. For each bond insurance company in our sample, we obtain its credit ratings history from S&P Capital IQ, and cross-check these data with other studies such as Bergstresser et al. (2010) and Cornaggia et al. (2020a). These data enable us to precisely identify changes in bond insurers' financial health.

Finally, we collect data on public drinking water quality from the U.S. Environmental Protection Agency (EPA). The EPA maintains a database called the Safe Drinking Water Information System (SWDIS), which contains information on local community water systems throughout the U.S., as required by the 1974 Safe Drinking Water Act (SDWA). The database contains records of federal violations of drinking water standards from 1980 to 2019, such as instances of community water systems containing contaminant levels that exceed the limits set forth by the SDWA.[5]. We use these data to identify changes in drinking water quality across municipalities in our sample.

We combine these data into a panel dataset of where each observation corresponds to a municipality-year record from 1980 to 2019. Each observation contains measures of municipality characteristics such as population, drinking water revenues, and investments into drinking water infrastructure. For each record, we also observe the total amount of municipal debt outstanding (insured and uninsured) raised for water infrastructure up to a given year. Each observation also contains information on federal violations of drinking water standards recorded for community water systems in a given municipality-year.

3.2 Descriptive Statistics

Table 1 presents summary statistics that describe all the municipalities for which we are able to collect data (columns denoted by "All Municipalities"). There are 3,134 unique municipalities that we are able to observe in the Census extracts. The data consists of large cities as well as small townships: the average number of people in a given municipality-year

[5]The database also maintains records of violations of approved water treatment techniques and reporting requirement failures

is 189.2 thousand, with a standard deviation of 648.6 thousand.

In terms of the water pollution experienced by municipalities, the average number of violations of federal drinking water standards set forth in the SDWA is 1.765 in a given municipality-year. Weighting this figure by the number of people exposed to these violations and aggregating across municipalities implies that 22.8 million people per year suffer from poor water quality in the U.S. (consistent with the estimates in Allaire et al. (2018)). Table 1 further shows a high standard deviation in the number of drinking water violations observed per year (unweighted and weighted by population), illustrating a long right-tail in the distribution of drinking water pollution across cities and towns.

Table 1 also characterizes municipal drinking water infrastructure. The annual drinking water service revenues earned by the average U.S. municipality is \$11.89 million between 1980 and 2019. For comparison, the average amount of annual property tax earned by a U.S. municipality over the same time period is approximately \$103.6 million. The average amount of annual municipal investment into drinking water infrastructure is \$8.131 million across all sample years. The high standard deviation of \$47.36 million in investment across all municipality-year observations reflects significant variation in infrastructure investment both across municipalities and over time within a given municipality.

When municipalities raise debt to finance investments in drinking water infrastructure, the average amount of debt raised is \$11.3 million. Aggregating these debt issuances over time and accounting for debt repayment, the average amount of municipal debt outstanding for water infrastructure is approximately \$107.8 million in a given year. This debt is primarily in the form of revenue bonds, which constitute approximately \$92.31 million in outstanding debt.

Table 1 and Figure 1 illustrate the cross-sectional and time-series distribution of insurance usage for municipal water bonds. For example, Table 1 shows that the four largest monoline insurers in the U.S.—FSA, MBIA, FGIC, and AMBAC—back the vast majority of insured debt in our sample. Figure 1 shows historically that when municipalities issue bonds for water infrastructure, they become increasingly reliant on bond insurance up until 2007. In 1980, the total municipal debt raised for water infrastructure is $2.4 billion; 7.33% of this debt is insured. In 2007, the total amount of water infrastructure debt raised is $26.2 billion; 47.5% of this debt is insured. In 2008, however, although $24.6 billion in municipal debt is raised for water infrastructure, the fraction of this debt that is insured is only 21.5%; the percentage of municipal debt that is insured further decreases to 8.93% in 2011.

Finally, for comparison with debt usage, Table 1 also describes other sources of financing used by municipalities for drinking water infrastructure. For example, intergovernmental transfers from federal, state, and local governments are approximately $0.664 million per year from 2013 to 2018 (the years when such data is available). Over the same time period, municipalities raise approximately $18.69 million in water infrastructure debt. These figures illustrate the relative importance of external debt as a source of capital for municipal water infrastructure, as compared to intergovernmental tax revenues and subsidies.

4 Empirical Framework

4.1 Identification Strategy

To estimate the causal effect of bond insurer deterioration on municipal outcomes, we study municipalities that use bond insurance when raising debt for water infrastructure. In particular, we devise an empirical identification strategy that exploits variation across municipalities in the amounts of municipal debt that are insured by different insurance companies. As of 2006 (prior to the crisis), all 11 bond insurance companies in our sample had AAA credit ratings. At that time, there was also significant heterogeneity across municipalities in the amounts of their debts that were insured by these companies (see Table 1). As discussed in Section 2, we assume that the pre-2006 variation in bond insurance across municipalities reflects individual optimization decisions by municipalities and insurance companies working to mitigate financial frictions.

The central identification assumption of our empirical strategy is that the credit rating downgrades of 9 out of the 11 bond insurance companies in our sample—which were triggered by the 2007 crash in structured product valuations—was unanticipated and exogenous to pre-crisis heterogeneity in insured debts across municipalities. In other words, we assume that pre-crisis heterogeneity in the amounts of municipal debts backed by various insurers was determined without the foresight that some AAA insurers would crash in value in 2007, while other AAA insurers would remain relatively unscathed.[6]

We use a credit rating downgrade for a bond insurance company as a proxy for a negative shock to the financing constraints faced by an insured municipality (i.e., a negative shock means that financing constraints become more severe). As discussed in Section **??**, the credit rating downgrade of an insurer signals a lower likelihood that the insurer will be able to meet their insurance obligations in case of municipal default. Such a downgrade thus proxies for lower effective pledgeable income available to the municipality, thereby worsening the external financing constraints faced by the local government. In other words, municipal default becomes more costly for new investors when existing insurers cannot meet their insurance obligations, which thus raises municipal bond yields.[7] For municipalities that use multiple bond insurers, we assume that the larger the total amount of insured debt that is backed by downgraded insurers, the larger is the negative shock to municipalities' financing constraints.

For each municipality, we measure the fraction of its total outstanding debt as of 2006 that is insured by any of the 9 insurers that are eventually downgraded. We compute the sample median of this fraction across municipalities in 2006, and then categorize each

[6] Cornaggia et al. (2020a) and Chun et al. (2018) establish that the stock prices and credit quality of insurers such as MBIA and AMBAC experience significant declines in 2007; we thus use 2007 as the first year of our treatment. All our results are robust to using 2008 as the start of our treatment.

[7] See Schwert (2017) and Chun et al. (2018) for work showing that municipal default risk is an important component of municipal bond yields.

municipality as having a "high" (above sample-median) or "low" (below sample-median) fraction of debt that insured by downgraded insurers. We characterize municipalities that have high (low) exposures to downgraded insurers as those that have larger (smaller) negative shocks to their financing constraints starting in 2007. We define our "treatment" sample as those municipalities that are subject to larger negative shocks to financing constraints, while our "control" sample consists of municipalities that experience smaller negative shocks to financing constraints.

To illustrate our identification strategy, it is helpful to consider a case study of two municipalities in our sample. Saline and Geary counties in Kansas both have approximately 68% of their outstanding municipal water debt insured by monoline insurers as of 2006; they both issue debt at an offering yield of 6%. However, while all of Geary county's insured debt is backed by MBIA, Saline County's debt is backed by two companies: 48% by MBIA and 20% by FSA. As illustrated in Figure 2, the median fraction of municipal debt that is insured by the downgraded insurers in our sample (which includes MBIA, but not FSA) is 53% in 2006. We thus assign Geary county to our "treatment" group, and we assign Saline county to our "control" group.

The municipalities that we analyze using this identification strategy are described in Table 1 ("Analysis Sample"). To enter the analysis sample, a municipality must have a positive amount of outstanding, insured debt as of 2006; there are 1,014 such municipalities in the data. As illustrated in Table 1, the analysis sample consists of municipalities are typically larger than the average U.S. municipality. For example, the average population for a given municipality-year observation in the analysis sample is 362.3 thousand, while the average amount of annual property tax revenues across all sample years is $194.2 million. These characteristics are to be expected, given that larger municipalities are more likely to use bond insurance to facilitate their capital needs.

Within the sample that we analyze, we present several pieces of empirical and anecdotal evidence to support our identification assumption. Table 2 shows that municipalities across the treatment and control samples have statistically indistinguishable characteristics across a number of observable pre-crisis metrics such as population, water revenues, property taxes, and external debt reliance. If anything, there is some evidence to suggest that treated municipalities actually had higher quality drinking water than control municipalities prior to 2007, which suggests that pre-shock differences in pollution are unlikely to bias the treatment effects in favor of our hypothesis (as we discuss later in the paper). Figure 3 further shows that the distribution of municipalities across the treatment and control samples is relatively well dispersed throughout the U.S., and not concentrated in geographic areas that might otherwise be subject to idiosyncratic economic trends. We offer further support for our identification assumption in Section 5.6.

4.2 Strengths and Limitations of Empirical Framework

Our empirical framework has several strengths and limitations. One strength of our framework is that our regression estimates are unlikely to reflect sample selection biases. The Census of Government Finances, SDC Platinum, and the EPA SWDIS aim to collect population-level data on various outcomes of interest. There are no obvious sampling biases in these databases that would suggest that we are only observing a particular set of municipalities for which the relationship between bond insurance and drinking water pollution would not be representative of all municipalities use bond insurance.

Another strength of our analysis is that we are able to observe granular data that are comparable across municipalities. For example, federal regulations on water quality apply equally across local jurisdictions, making drinking water pollution measures comparable across regions. Additionally, bond insurance companies typically insure municipal debts across a wide range of geographic locations using broadly similar practices. These aspects of our data enable us to provide accurate and precise regression estimates of the impact of bond insurance shocks on drinking water pollution.

One limitation of our analysis is that our estimates are applicable only to those municipalities that use bond insurance for water infrastructure financing; we are unable to assess the potential impact of bond insurance on municipalities that do not use insurance. We exclude municipalities that do not use bond insurance from our analysis to improve the plausibility of our identification assumptions, as municipalities that rely on bond insurance likely differ from those that do not, along unobservable dimensions (for example, following Thakor (1982), municipalities that use bond insurance are of relatively higher credit quality).[8] Because municipalities that use bond insurance contain a large majority (73%) of the U.S. population, however, we believe that our findings are still of importance, as they describe how bond insurance matters for a significant number of people who rely on public drinking water.

5 Findings

5.1 Borrowing Costs

The first empirical prediction of our hypothesis is that treated municipalities, i.e. those municipalities that historically relied more heavily on downgraded insurers, experience a larger increase in borrowing costs relative to municipalities in the control group. To test this prediction, we estimate a "difference-in-difference"-like measure of the relative increase in bond yields for new revenue bond issues by treatment versus control municipalities around 2007. Specifically, we estimate the following regression specification:

$$BondYield_{i,t} = \alpha_1 + \beta_1 \cdot Treatment_{i,t} + \beta_{c,1} \cdot Controls_{i,t} + y_i + v_t + \epsilon_{i,t} \quad (1)$$

[8] See Cornaggia et al. (2020a) for empirical analysis of municipality bond insurance choice models.

where for municipality i in year t, $BondYield_{it}$ is the weighted average of the yields on new revenue bonds issued by municipality i in year t (where the weights are the dollar amounts of each issuance). $Treatment_{i,t}$ is a binary indicator of whether municipality i is in the treatment group and year t is 2007 or later. $Controls_{i,t}$ include the (log) weighted average maturity of the new revenue bonds issued by municipality i in year t, the logarithm of the total new revenue bonds issued by municipality i in year t, the (log) number of drinking water health violations observed in municipality i in year $t-1$, the (log) amount of drinking water service revenues earned by municipality i in year $t-1$, the (log) amount of pre-existing debt outstanding (which includes both revenue bonds and general obligation bonds) of municipality i in year t, the (log) of property taxes, the fraction of debt outstanding that is insured in year t, and the (log) population of municipality i in year $t-1$. We also include municipality and year fixed effects, and standard errors are clustered by municipality and year.

The main regressor of interest is $Treatment_{i,t}$. Under our central identification assumption, the estimated coefficient for $Treatment_{i,t}$ provides a measure of the causal effect of bond insurer downgrades on the cost of new municipal debt financing. The various controls added to the regression proxy for factors that likely influence borrowing costs, such as municipal income (service revenues), investment needs (drinking water health violations), the total amount of debt that is insured, and proxies for general economic conditions (population and property taxes). Municipality fixed effects are included to control for time-invariant components of borrowing costs for a given municipality. Year fixed effects control for aggregate changes in borrowing costs across all municipalities in a given year.

Table 3 depicts the regression estimates for Specification (1). The columns in Table 3 illustrate coefficient estimates for the specification with increasing numbers of controls, to illustrate the robustness of the results across model choice. The coefficient estimate for $Treatment$ is approximately 14 basis points across all specifications (and statistically significant at the 5% level), implying that borrowing costs increase from 5.16% to 5.3% *ceteris paribus* (see Table 2). The coefficient estimates for $Treatment$ are remarkably stable across columns. These statistics suggest that the treatment effect estimates are robust to different empirical specifications.

The findings are consistent with our hypothesis: bond insurer downgrades lead to significantly higher costs of municipal debt financing. This result holds true even as municipalities remain solvent, as municipal defaults are rarely observed in our sample. The evidence shows that the crash in structured product valuations, which triggered the credit events observed for bond insurance companies in 2007, have a tangible effect on the costs of external financing facing municipalities.

5.2 Debt Servicing Expenses

To verify that municipalities actually pay higher debt servicing fees—as opposed to simply face higher costs of external financing that they may not meet in practice—we analyze Census data on the debt servicing costs paid by municipalities. We estimate the following regression specification:

$$Log(Debt\ Servicing\ Expense_{i,t}) = \alpha_2 + \beta_2 \cdot Treatment_{i,t} + \beta_{c,2} \cdot Controls_{i,t} + y_i + v_t + \epsilon_{i,t} \quad (2)$$

where $Log(Debt\ Servicing\ Expense_{i,t})$ is the logarithm of the total amount of debt servicing fees paid for municipality i in year t. All other variables remain broadly the same as in Specification (1) (we exclude debt maturity and issue size). This measure of debt servicing fees captures not only payments made on new debt issuances, but also payments on outstanding debts. The regression coefficient for $Treatment$ provides a measure of the impact of insurer downgrades on the total amount of debt financing costs paid by municipalities.

Table 4 depicts the regression results. The treatment effect estimate is at least 0.101

across all columns. The results imply that treated municipalities pay approximately 10.6% higher debt servicing fees following the credit rating shock to monoline insurers. Because the average county in the control group pays debt servicing fees of \$1.257 million per year (see Table 2), this coefficient implies that the counties in our sample spend \$135 million more in debt servicing fees annually following the shock ($\approx 1,014 \cdot (\exp(10.1\%) - 1) \cdot 1.257$).

The coefficient estimate remains stable across different specifications that vary in the numbers of controls that are included in the regression. These estimates further reinforce our hypothesis about the link between insurer downgrades and borrowing costs. The results illustrate that treated municipalities pay greater debt servicing fees following insurer rating downgrades, likely reflecting not only the higher costs of new debt financing (as shown in Table 3), but also relatively less favorable terms of refinancing on existing debt.

5.3 Debt Outstanding

A second prediction of our hypothesis is that when municipalities face higher borrowing costs due to credit rating downgrades of their bond insurers, they will raise less external financing. To test this prediction, we examine changes in the levels of debt outstanding held by municipalities following the 2007 shock to insurer credit ratings. Specifically, we estimate the following regression specification:

$$Log(Debt\ Outstanding_{i,t}) = \alpha_3 + \beta_3 \cdot Treatment_{i,t} + \beta_{c,3} \cdot Controls_{i,t} + y_i + v_t + \epsilon_{i,t} \quad (3)$$

where $Log(Debt\ Outstanding_{i,t})$ is the logarithm of the total amount of debt outstanding held by municipality i in year t. All other variables remain the same as in Specification (2). The regression coefficient for $Treatment$ provides an estimate of how the 2007 credit rating downgrades to insurers affects the total amount debt held by a municipality.

The results are presented in Table 5. The coefficient for $Treatment_{i,t}$ is at least -0.021 across all columns, and remains similar in magnitude under different regression specifications.

The results indicate that treated municipalities reduce their outstanding debt by at least 2% per year relative to municipalities in the control group following the 2007 shock to bond insurer credit ratings. Because the average municipality in the control group has \$59.88 million in revenue bonds outstanding (see Table 2), this coefficient implies that the municipalities in our sample raise \$1,499 million less revenue debt annually after the shock ($\approx 1014 \cdot (\exp(2.5\%) - 1) \cdot 59.88$). The data therefore suggest that municipalities respond to higher borrowing costs by reducing their reliance on external debt financing. Consistent with our hypothesis, the insurers' credit rating downgrades in 2007 appear to have hampered treated municipalities' access to credit by exacerbating their financing constraints.

5.4 Investment in Public Drinking Water Infrastructure

A third prediction of our hypothesis is that negative shocks to insurer credit ratings should cause municipalities to cut back on investment in drinking water infrastructure. To test this prediction, we examine changes in the levels of investment into water infrastructure by municipalities around the 2007 shock to insurer credit ratings. Specifically, we estimate the following regression specification:

$$Log(Investment_{i,t}) = \alpha_4 + \beta_4 \cdot Treatment_{i,t} + \beta_{c,4} \cdot Controls_{i,t} + y_i + v_t + \epsilon_{i,t} \qquad (4)$$

where $Log(Investment_{i,t})$ is the logarithm of the total amount of investment into public drinking water infrastructure by municipality i in year t . As explained in Table A1, investment in drinking water infrastructure encompasses the servicing of pipes, upkeeping of supply stations and water treatment facilities, etc. All other variables in Specification (4) remain the same as in Specification (2). The regression coefficient for $Treatment_{i,t}$ provides an estimate of how the 2007 shock to insurer credit ratings affects municipalities' investments into drinking water infrastructure.

The results are presented in Table 4. The regression coefficient for $Treatment$ ranges from approximately -2.7% to -3.7% across all columns, illustrating the robustness of the estimates to specification choice. The estimates show that treated municipalities reduce investment into public drinking water infrastructure (relative to control municipalities) by approximately 4% annually, following the credit ratings downgrades of bond insurers. Because the average municipality in the control group invests \$8.362 million in drinking water infrastructure per year (see Table 2), this coefficient implies that the municipalities in our sample invest \$274 million less capital per year in drinking water infrastructure after the shock ($\approx 1014 \cdot (\exp(3.3\%) - 1) \cdot 8.362$).

Taken together with the evidence presented in Tables 3 through 5, the evidence is consistent with our hypothesis. When bond insurer credit ratings decrease, increases in municipal borrowing costs and reductions in borrowing amounts lead to lower investment in public drinking water infrastructure.

5.5 Drinking Water Pollution

A fourth prediction of our hypothesis is that negative shocks to insurer credit ratings should cause municipalities to experience higher levels of drinking water pollution, due to their reductions in water infrastructure investment. To test this prediction, we examine changes in the levels of drinking water pollution in municipalities following the 2007 shock to insurer credit ratings. Specifically, we estimate the following regression specification:

$$Log(Water\ Quality\ Health\ Violations_{i,t}) = \alpha_5 + \beta_5 \cdot Treatment_{i,t} + \beta_{c,5} \cdot Controls_{i,t} + y_i + v_t + \epsilon_{i,t} \tag{5}$$

where $Log(Water\ Quality\ Health\ Violations_{i,t})$ is the logarithm of the total number of violations of federal health standards for drinking water (as specified by the U.S. Safe Drinking Water Act) observed in municipality i in year t. All other variables remain the same as in Specification (2). The regression coefficient for $Treatment$ provides an estimate of how the

2007 shock to insurer credit ratings affects municipalities' drinking water quality.

The results are presented in Table 7. The regression coefficient for $Treatment$ across all columns ranges between 0.06 and 0.07. The estimates imply that violations of federal drinking water health standards increase in municipalities that rely on bond insurers that become downgraded in 2007. Because the average municipality in the control group has 2.688 drinking water violations in a given year (see Table 2), this coefficient implies that municipalities in our sample have 165 more water violations per year following the shock ($\approx 1014 \cdot (\exp(5.88\%) - 1) \cdot 2.688$), or equivalently 458,433 more people being exposed to an additional drinking water health violation each year ($\approx 1014 \cdot (\exp(5.88\%) - 1) \cdot 7465$). These findings are consistent with the view that the observed reductions in water infrastructure investment triggered by insurer credit rating downgrades has real effects: lower quality drinking water.

5.6 Alternative Explanations

5.6.1 Causal Inference

We perform a number of analyses to critically evaluate whether our main findings characterize the causal effect of bond insurance shocks on municipal outcomes. One alternative explanation for the findings is that treated municipalities experienced a greater deterioration of general economic conditions during the crisis than control municipalities. Perhaps insurers that invested in structured financial products were more likely to insure bonds issued by municipalities that later suffered a greater decline during the crisis. This alternative hypothesis can be formulated as an omitted factor (i.e. general economic conditions and/or future expectations) in our regression analysis.

There are several pieces of evidence that are inconsistent with this hypothesis. First, Table 2 and Figure 4 show that there is little evidence that treated municipalities and control municipalities appeared to be heading in different directions prior to the crisis. Table

2 shows that municipalities across the treatment and control samples appear observationally equivalent across a number of pre-crisis metrics such as population, water revenues, property taxes, and external debt reliance. If anything, there is some evidence to suggest that treated municipalities actually had higher quality drinking water than control municipalities prior to 2007. Figure 4 shows that time-series trends in borrowing costs, investment behavior, and water quality are statistically indistinguishable between the two groups prior to the 2007 shock.

Third, Table 8 shows that there are no significant differences in drinking water revenues in the immediate years following the 2007 shocks to bond insurer credit ratings. We estimate Specification (4), but use the logarithm of water service revenues for municipality i in year t as the dependent variable (all other variables remain the same as in Specification (4), except we exclude water revenues as a control). If the observed increases in municipal borrowing costs for revenue bonds are driven by contemporaneous negative shocks to the revenue streams generated by drinking water consumption, then we should expect to see a negative association between water service revenues and credit rating downgrades of insurers in the immediate years surrounding the 2007 shock. Our findings to the contrary, however, suggest that there are no demand-side reductions in municipalities' pledgeable income sources that might otherwise explain increased borrowing costs after 2007.

Fourth, Table 9 shows that even after the 2007 insurer credit rating downgrades, treatment and control municipalities do not show significant differences in outcomes such as population growth or property taxes—proxies for general economic conditions that might otherwise explain municipal borrowing costs or infrastructure investment needs. In Table 9, we estimate Specification (4), but use the logarithms of municipal population (Panel A) and property taxes (Panel B) as the dependent variables; all other variables remain the same as in the original specification (though we remove the lagged outcome variables from the controls). The coefficient for the treatment effect is statistically insignificant across all columns. These findings reinforce the interpretation of the main results, i.e. that the observed differences between treatment and control municipalities in borrowing costs and investment behavior after 2007 are driven by financing frictions rather than general, unobservable economic conditions.

Fifth, we show that our results hold primarily for revenue bonds, which comprise 86% of all municipal debt raised for water infrastructure; our results do not hold for general obligation bonds. Drinking water revenue bonds are securities that are raised specifically for drinking water infrastructure investments; the interest and principal repayments for these bonds are restricted to the cash flows generated by these projects. In contrast, general obligation bonds are securities whose debt servicing costs can be sourced from any income streams available to a municipality, including service fees for projects that exist outside of water infrastructure.

If treatment and control municipalities experience differential trends in general economic conditions after 2007, we should be more likely to observe our main results for G.O. bonds, rather than revenue bonds alone. Table 10 shows results for Specifications 1 and 2, estimated using G.O. bond yields and G.O. bond amounts as dependent variables. The treatment effect coefficients across all columns of Panels A and B of Table 10 illustrate that the 2007 credit rating downgrades of bond insurers are not associated with significant changes in G.O. bond yields or G.O. borrowing amounts. These results suggest that general economic conditions are unlikely to explain our main results. Instead, the evidence is more supportive of our main hypothesis: that changes in municipal borrowing costs and investment behavior are driven by tighter financing constraints triggered by the bond insurance industry.

5.6.2 Alternative Mechanisms

In our final analysis, we present suggestive evidence that sheds light on the specific frictions that underlie our results. Our main findings are consistent with bond insurance serving as a signalling device that municipalities use to overcome adverse selection. Thakor (1982) further suggests that a negative shock to bond insurance will be especially relevant for high quality municipalities who purchase costly insurance to signal their quality to uninformed investors. We support this view by showing in Table 11 that our results on borrowing costs, debt amounts, infrastructure investment, and water pollution are stronger for higher quality municipalities, where quality is (coarsely) proxied by property tax revenues per capita.

Other frictions that have been cited as motivations for bond insurance appear less relevant to our empirical results. For example, Nanda and Singh (2004) argue that municipal bond insurance exists as a means of preserving the tax-exempt status of municipal payouts during default. Their paper suggests that a negative shock to bond insurance should be particularly relevant to bonds of longer maturity. We test this prediction by estimating our results across municipalities that have outstanding debts of varying years until maturity. Table 12 shows mixed evidence for this prediction. Our results on financing expenses and infrastructure investment support this channel, whereas our results on borrowing costs, debt amounts, and water pollution do not support this channel.

As another example, some studies suggest that negative shocks to bond insurers will reduce investor demand for municipal debt. These changes may stem from credit-ratings based regulatory constraints (Becker and Ivashina, 2015; Chen et al., 2014; Calabria and Ekins, 2013; Ellul et al., 2011; Stanton and Wallace, 2017), window-dressing objectives (Lakonishok et al., 1991), or retail investor responses to bond ratings (Cornaggia et al., 2018; Adelino et al., 2017). The results in Bergstresser et al. (2010), however, show that municipal investors who face such as incentives, such as mutual funds and insurance companies, do not significantly reduce their holdings of insured municipal debt after 2007. These findings suggest that changes in investor demand for municipal debt are unlikely to explain our results.

6 Conclusion

This paper presents empirical evidence that the U.S. drinking water crisis can be partly attributed to the collapse of the municipal bond insurance industry in 2007. The findings are consistent with the hypothesis that credit rating downgrades of municipal insurers exacerbate financing frictions faced by local governments. We show that municipalities that had previously relied heavily on bond insurers that become downgraded due to their involvement in structured financial products, cut their investments into public drinking water infrastructure. These reductions in infrastructure investment are associated with subsequent increases in drinking water pollution.

The findings illustrate that the failure to provide safe drinking water—perhaps the most critical public good provided by local governments—can be traced back to financial market disruptions. More broadly, the evidence in this paper suggests that theories of financial market imperfections, which are typically studied in the context of private corporations and households, can be useful for explaining how well municipalities are able to meet public infrastructure needs. Further exploring the ways in which theories in financial economics can—and cannot—explain the provision of public goods is thus an important area for future research.

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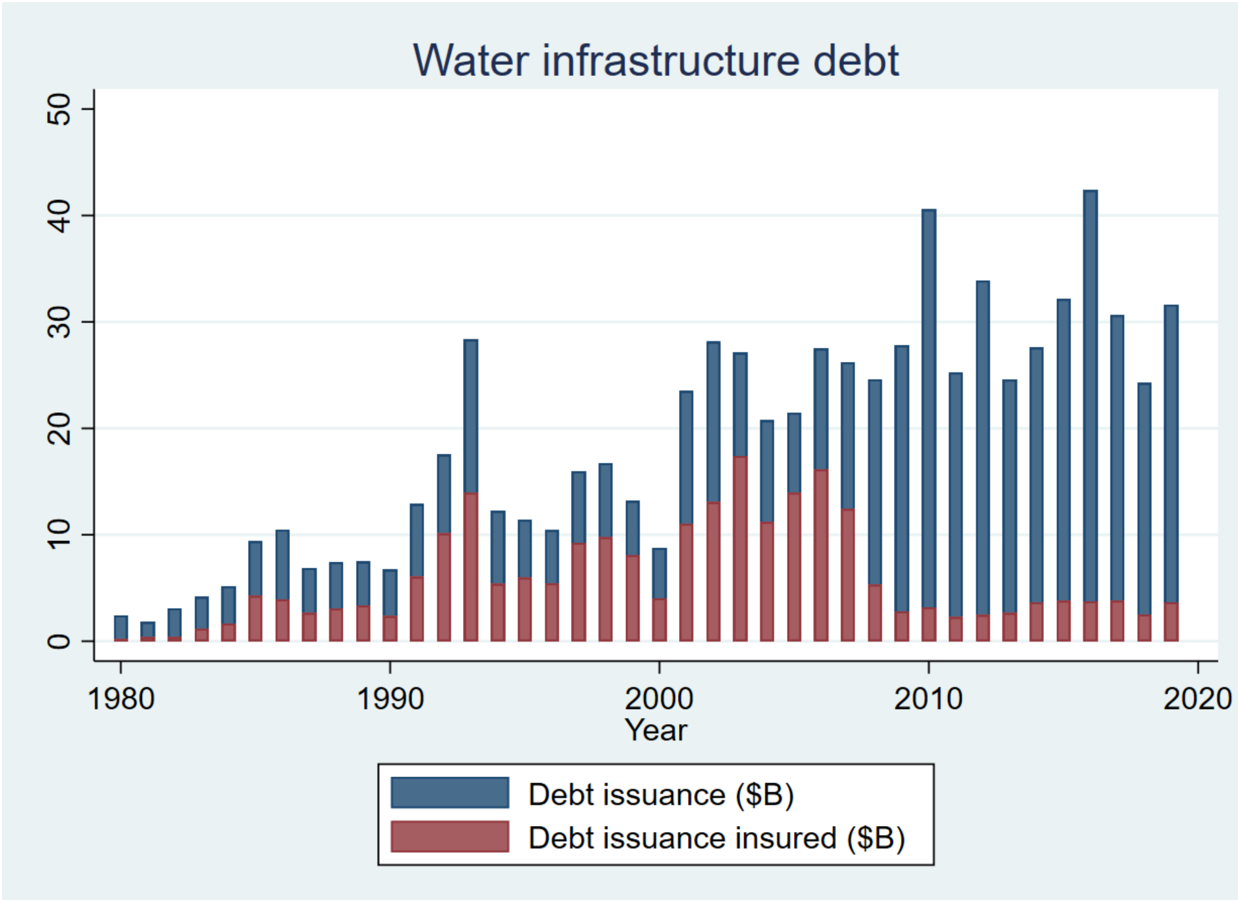

Figure 1: Time-Series of Municipal Debt Issuances

This figure illustrates the time-series of new municipal debt issued each year for drinking water infrastructure investment, in terms of the total debt issued as well as the total amount of insured debt issued, by municipalities in our sample. The x-axis depicts the year of observation, while the y-axis depicts the dollar amount of total debt issued (in millions).

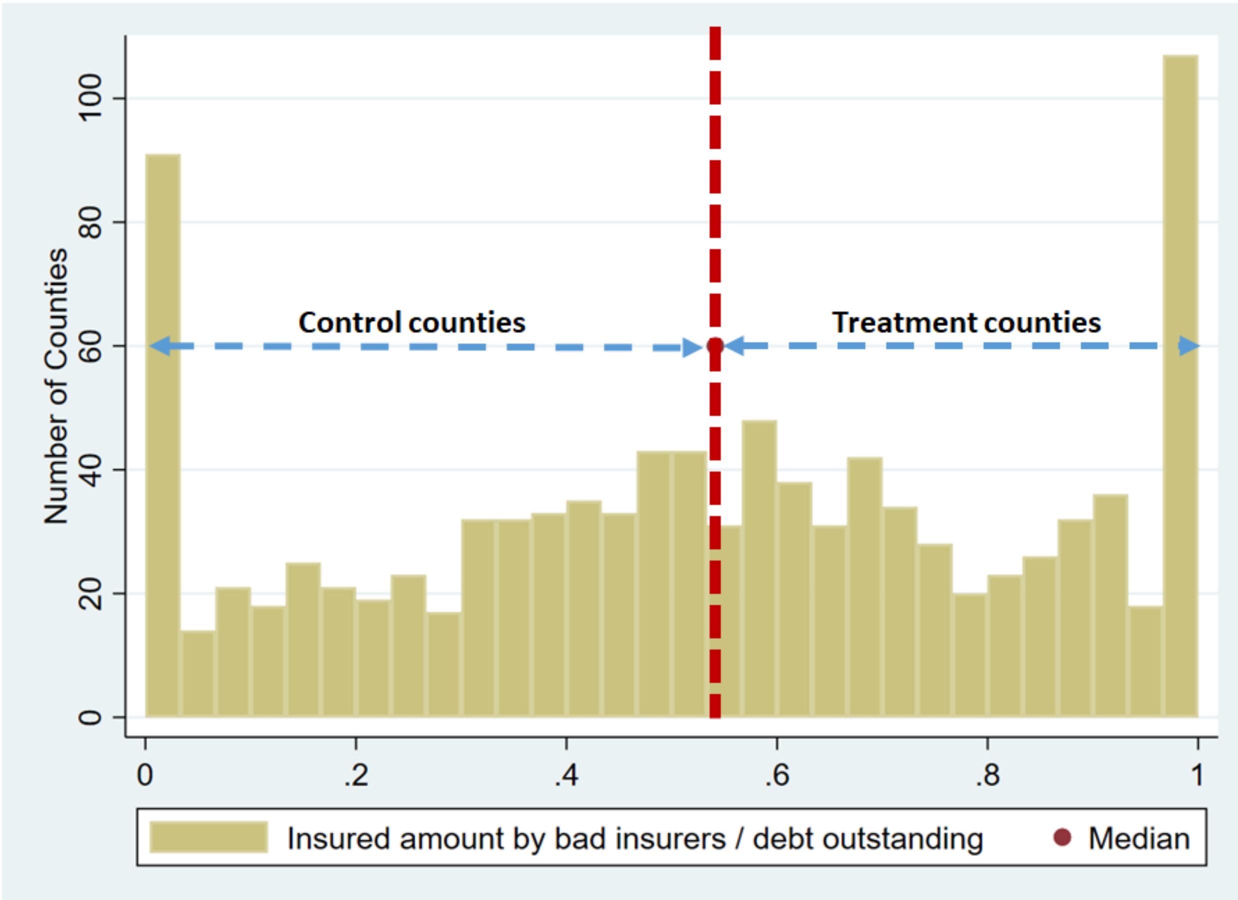

Figure 2: Distribution of Municipal Debt Insured by Downgraded Insurers

This histogram depicts the distribution of municipal debt that is insured by downgraded monoline insurers. The x-axis depicts the fraction of total outstanding debt (by municipality) in 2006 that is backed by monoline insurers that receive credit rating downgrades during the crisis. The y-axis depicts the number of sample municipalities that correspond to each interval of insured debt amounts. The median percentage of outstanding debt that is insured by downgraded insurers in the sample if 53%, depicted by the red dashed line. Municipalities in the "treatment" ("control") group have above (below) sample-median percentages of outstanding debt insured by downgraded insurers.

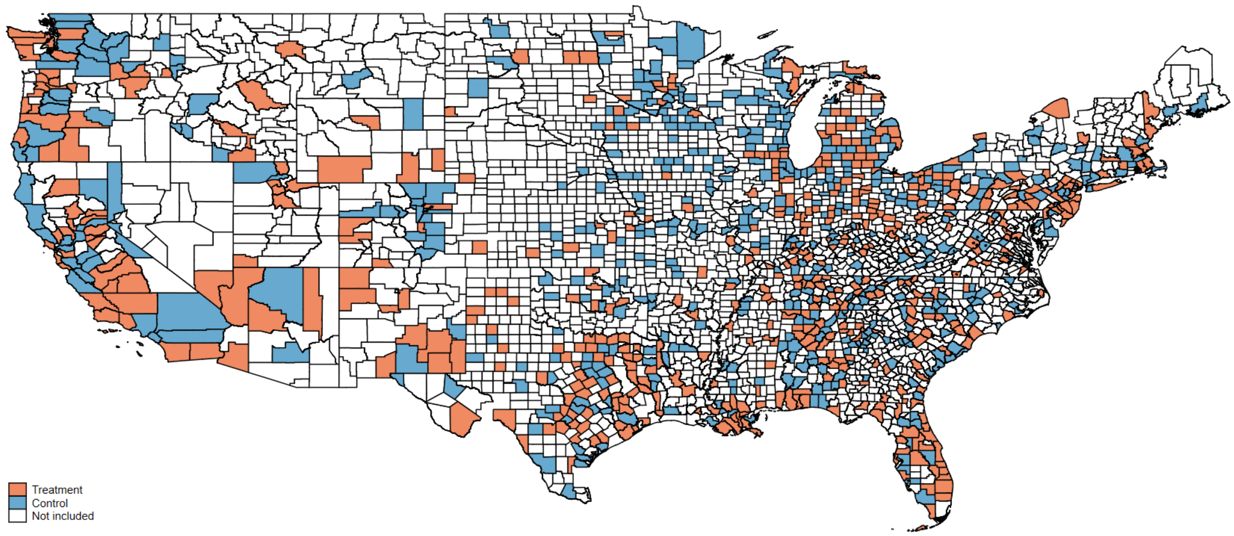

Figure 3: Control Vs. Treatment Municipalities

This heat map depicts municipalities that comprise the control and treatment samples in our analysis. Treatment (control) municipalities refer to municipalities that have above (below) sample median issuance of debt in 2006 that is insured by monoline companies that become downgraded in 2007 and/or stop insuring municipal debt.

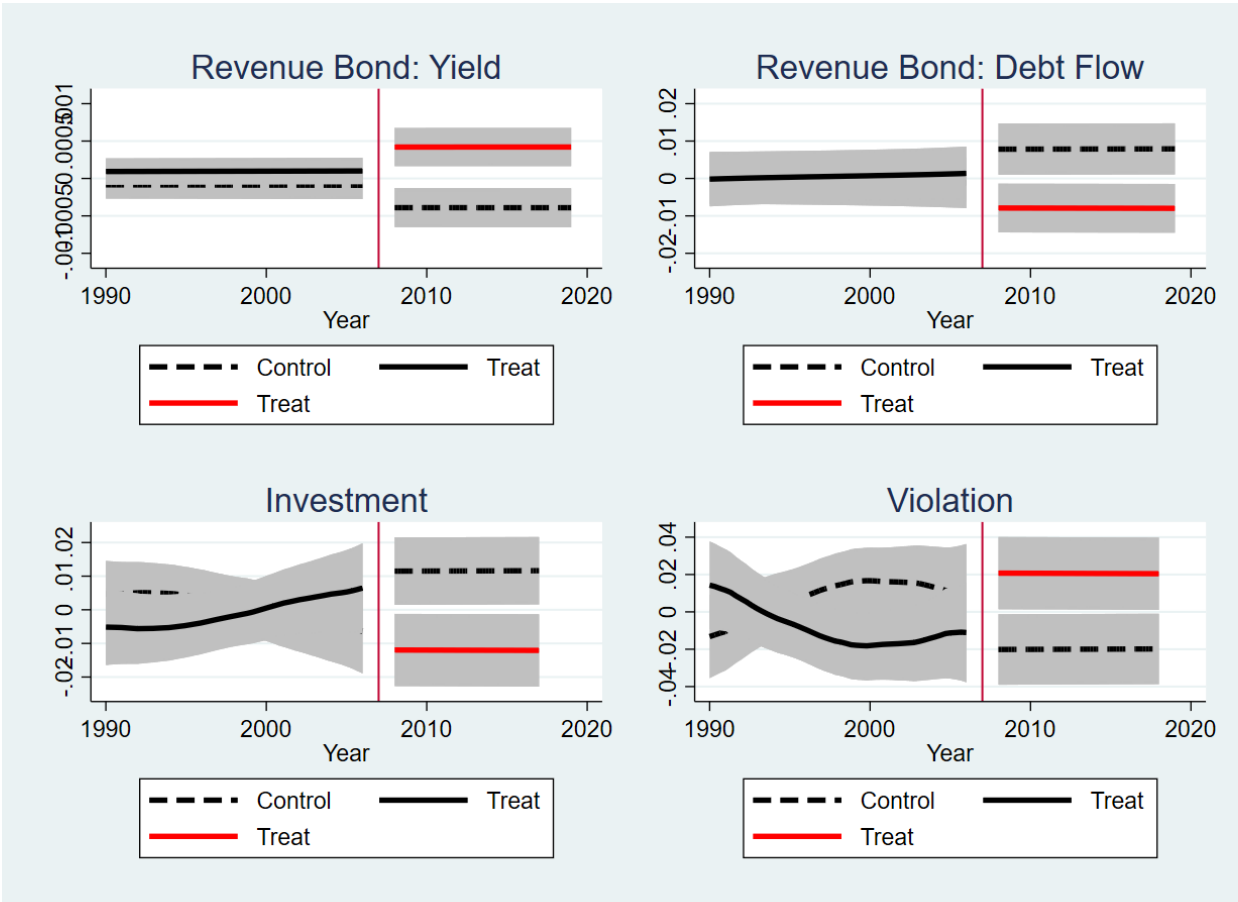

Figure 4: Graphical Illustration of Treatment Effect over Time

This figure illustrates time-varying regression estimates of the average residual differences between treatment and control municipalities' borrowing costs (Yield), outstanding debt amounts (Debt Flow), investment into water infrastructure (Investment), and drinking water pollution levels (Violations), after controlling for municipality characteristics. 95% confidence intervals are depicted in gray.

Table 1: Sample Descriptive Statistics

This table presents sample descriptive statistics for the municipalities that comprise our dataset. Variable definitions are provided in Table A1. For each characteristic listed in the panel, the sample size, mean, standard deviation, min and max of the characteristic across municipalities is presented.

	All Municipalities			Analysis Sample		
	N	Mean	SD	N	Mean	SD
Main Outcome Variables						
Offering yield	66,188	0.0594	0.0165	37,885	0.0587	0.0155
Water interest expense (M)	86,792	1.771	17.04	33,198	3.156	13.29
Debt outstanding (M)	66,519	107.8	884.5	37,935	184.7	1,165
Revenue debt outstanding (M)	66,519	92.31	842.9	37,935	159.2	1,111
Debt issuance (M)	66,519	11.30	104.2	37,935	19.24	137.1
Water investment (M)	86,792	8.131	47.36	33,198	16.31	73.15
# SDWA Violations	106,920	1.765	7.571	40,400	2.340	10.22
# SDWA Violations pop wgt (K)	106,920	8.550	81.21	40,400	17.28	124.2
Explanatory Variables						
Water revenue (M)	86,792	11.89	68.17	33,198	23.54	101.8
Population (K)	86,792	189.2	648.6	33,198	362.3	935.7
Property tax (M)	86,792	103.6	470.2	33,198	194.2	581.4
Debt insured (M)	66,519	44.10	277.8	37,935	77.12	364.4
Dummy: Rated by Moody's	119,922	0.0371	0.189	40,552	0.0936	0.291
Moody's Rating (weighted)	4,446	15.63	5.500	3,795	15.53	5.485
Dummy: Investment grade (Moody's)	4,446	0.829	0.377	3,795	0.823	0.382
Debt Insured by Insurers (M)						
FSA	66,519	7.940	69.06	37,935	13.84	90.99
Assured Guaranty	66,519	0.630	9.493	37,935	1.067	12.53
MBIA	66,519	11.31	73.78	37,935	19.82	96.83
FGIC	66,519	12.72	109.7	37,935	22.30	144.5
AMBAC	66,519	8.621	51.74	37,935	15.09	67.80
XL Capital Assurance Inc.	66,519	0.771	17.69	37,935	1.348	23.41
Radian Asset Assurance Inc.	66,519	0.346	10.89	37,935	0.606	14.42
CIFG NA	66,519	0.0912	1.778	37,935	0.158	2.352
ACA Financial Guaranty	66,519	0.0226	0.559	37,935	0.0397	0.740
Intergovernmental Funds (M): 2013-2018						
Debt issuance (M)	9,712	18.69	141.5	5,769	30.28	181.5
Intergovernmental revenue: Federal (M)	9,712	0.108	0.976	5,769	0.143	1.176
Intergovernmental revenue: State (M)	9,712	0.289	2.105	5,769	0.408	2.556
Intergovernmental revenue: Local (M)	9,712	0.267	4.052	5,769	0.429	5.244

Table 2: Comparison of Municipalities in the Treatment and Control Samples

This table presents descriptive statistics for municipalities that comprise the treatment and control samples in our analysis. Variable definitions are provided in Table A1. For each characteristic listed in the panel, the sample size, mean, and standard deviation of the characteristic across municipalities is presented. T-test statistics for the differences in mean characteristics between treatment and control samples are also shown. The sample year is 2006.

	Control			Treatment			T-test
	N	mean	sd	N	mean	sd	Control−Treatment
Water revenue (M)	389	12.53	12.78	376	13.65	12.68	−1.22
Water interest expense (M)	389	1.257	1.685	376	1.380	1.642	−1.02
Water investment (M)	389	8.362	8.412	376	9.165	8.562	−1.31
Population (K)	389	259.8	256.0	376	264.8	263.7	−0.27
Property tax (M)	389	135.2	128.0	376	135.7	130.6	−0.05
Dummy: Rated by Moody's	507	0.195	0.397	507	0.168	0.374	1.11
Moody's Rating (weighted)	99	16.48	3.985	85	16.16	5.201	0.46
Dummy: Investment grade (Moody's)	99	0.838	0.370	85	0.859	0.350	−0.40
Debt outstanding (M)	507	63.11	81.33	507	66.66	82.89	−0.69
Rev debt outstanding (M)	507	59.88	91.46	507	63.94	91.38	-0.71
Debt issuance (M)	507	2.837	4.577	507	3.087	4.871	−0.84
Offering yield	507	0.0516	0.00796	507	0.0520	0.00721	−0.84
# SWDA Violations	506	2.688	3.210	504	2.274	2.934	2.14
# SWDA Viol. pop wgt (K)	506	7.465	10.91	504	6.623	10.55	1.25

Table 3: Effects of Bond Insurer Downgrades on Municipal Borrowing Costs

This table presents OLS regression estimates of the effects of bond insurer credit rating downgrades on the cost of municipal debt financing for public drinking water infrastructure. The dependent variable is the weighted average yield in percentages on revenue bonds offered by a municipality in a given year (where the weights are the bond amounts). The key independent variable of interest is *Treatment*: an interaction term between whether a given observation is taken in 2007 or afterwards, and whether a given municipality has a high or low (i.e. above- or below- the 2006 sample median) fraction of outstanding debt that is insured by downgraded monoline companies. Controls are described in Table A1. The sample period is from 1980-2019. Standard errors are clustered at the municipality and year level.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Treatment	0.137**	0.137**	0.136**	0.136**	0.136**	0.140**	0.141**
	(0.0641)	(0.0640)	(0.0639)	(0.0637)	(0.0638)	(0.0626)	(0.0627)
Maturity	0.0313	0.0315	0.0309	0.0331	0.0333	0.0245	0.0246
	(0.0241)	(0.0241)	(0.0241)	(0.0243)	(0.0242)	(0.0238)	(0.0239)
Debt issuance	−0.146***	−0.145***	−0.147***	−0.148***	−0.148***	−0.160***	−0.161***
	(0.0310)	(0.0310)	(0.0311)	(0.0316)	(0.0317)	(0.0306)	(0.0306)
Lag log violation		0.0102	0.0105	0.0104	0.0105	0.0103	0.0102
		(0.0137)	(0.0136)	(0.0136)	(0.0136)	(0.0136)	(0.0136)
Lag log water revenue			0.0504	0.0381	0.0418	0.0483	0.0483
			(0.0402)	(0.0388)	(0.0358)	(0.0352)	(0.0351)
Lag log debt out'				0.0326	0.0341	0.0218	0.0218
				(0.0331)	(0.0319)	(0.0312)	(0.0313)
Lag log property tax					−0.0117	0.0249	0.0255
					(0.0496)	(0.0558)	(0.0553)
Lag log population						−0.0665	−0.0670
						(0.0450)	(0.0447)
Total insurance frac						0.276***	0.277***
						(0.0850)	(0.0854)
Moody rating							2.55e-05
							(0.00313)
Is rated by Moody							0.00871
							(0.0577)
Observations	9,513	9,513	9,513	9,513	9,513	9,513	9,513
County FE	YES	YES	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES	YES	YES

Robust standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 4: Effects of Bond Insurer Downgrades on Municipal Debt Servicing Expenses

This table presents OLS regression estimates of the effects of bond insurer credit rating downgrades on the total financing costs paid by municipalities for debt raised for public drinking water infrastructure. The dependent variable is the logarithm of the total interest, principal, and other financing costs paid by a municipality in a given year. The key independent variable of interest is *Treatment*: an interaction term between whether a given observation is taken in 2007 or afterwards, and whether a given municipality has a high or low (i.e. above- or below- the 2006 sample median) fraction of outstanding debt that is insured by downgraded monoline companies. Controls are described in Table A1. The sample period is from 1980-2019. Standard errors are clustered at the municipality and year level.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Treatment	0.102***	0.102***	0.101***	0.102***	0.101***	0.101***	0.101***
	(0.0335)	(0.0334)	(0.0317)	(0.0310)	(0.0307)	(0.0308)	(0.0308)
Lag log violation		0.00809	0.00836	0.00888	0.00879	0.00838	0.00825
		(0.00896)	(0.00854)	(0.00822)	(0.00823)	(0.00831)	(0.00831)
Lag log water revenue			0.210***	0.172***	0.166***	0.163***	0.163***
			(0.0270)	(0.0258)	(0.0273)	(0.0270)	(0.0270)
Lag log debt out'				0.104***	0.102***	0.102***	0.101***
				(0.0113)	(0.0113)	(0.0117)	(0.0118)
Lag log property tax					0.0185	0.00849	0.00919
					(0.0210)	(0.0265)	(0.0265)
Lag log population						0.0200	0.0193
						(0.0208)	(0.0209)
Total insurance frac						0.0526*	0.0536*
						(0.0309)	(0.0306)
Moody rating							1.54e-06
							(0.00244)
Is rated by Moody							0.0123
							(0.0446)
Observations	11,609	11,609	11,609	11,609	11,609	11,589	11,589
County FE	YES	YES	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES	YES	YES

Robust standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 5: Effects of Bond Insurer Downgrades on Municipal Debt Outstanding

This table presents OLS regression estimates of the effects of bond insurer credit rating downgrades on the amounts of municipal debt raised for public drinking water infrastructure. The dependent variable is the logarithm of the total amount of outstanding revenue bonds offered by a municipality in a given year. The key independent variable of interest is *Treatment*: an interaction term between whether a given observation is taken in 2007 or afterwards, and whether a given municipality has a high or low (i.e. above- or below-the 2006 sample median) fraction of outstanding debt that is insured by downgraded monoline companies. Controls are described in Table A1. The sample period is from 1980-2019. Standard errors are clustered at the municipality and year level.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Treatment	−0.0208*	−0.0211*	−0.0209*	−0.0216*	−0.0219**	−0.0250**	−0.0254**
	(0.0106)	(0.0107)	(0.0107)	(0.0107)	(0.0107)	(0.0113)	(0.0113)
Lag log revenue debt out'	0.921***	0.921***	0.920***	0.890***	0.890***	0.889***	0.886***
	(0.00969)	(0.00970)	(0.00989)	(0.0112)	(0.0112)	(0.0120)	(0.0123)
Lag log violation		0.00368	0.00369	0.00459	0.00453	0.00412	0.00242
		(0.00365)	(0.00365)	(0.00358)	(0.00357)	(0.00344)	(0.00342)
Lag log water revenue			0.0103**	0.00644	0.00341	0.00447	0.00528
			(0.00497)	(0.00526)	(0.00522)	(0.00550)	(0.00535)
Lag log debt out'				0.0407***	0.0400***	0.0314***	0.0317***
				(0.00910)	(0.00912)	(0.00922)	(0.00945)
Lag log property tax					0.0106	0.0120	0.0232***
					(0.00669)	(0.00758)	(0.00801)
Lag log population						−0.00128	−0.00964*
						(0.00539)	(0.00553)
Total insurance frac						0.137***	0.150***
						(0.0367)	(0.0357)
Moody rating							−0.00196
							(0.00129)
Is rated by Moody							0.182***
							(0.0231)
Observations	27,583	27,583	27,583	27,583	27,583	27,566	27,566
County FE	YES	YES	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES	YES	YES

Robust standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 6: Effects of Bond Insurer Downgrades on Municipal Investment in Drinking Water Infrastructure

This table presents OLS regression estimates of the effects of bond insurer credit rating downgrades on municipal investment into public drinking water infrastructure. The dependent variable is the logarithm of the total investment into drinking water infrastructure by a municipality in a given year. The key independent variable of interest is *Treatment*: an interaction term between whether a given observation is taken in 2007 or afterwards, and whether a given municipality has a high or low (i.e. above- or below- the 2006 sample median) fraction of outstanding debt that is insured by downgraded monoline companies. Controls are described in Table A1. The sample period is from 1980-2019. Standard errors are clustered at the municipality and year level.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Treatment	−0.0365	−0.0373	−0.0271*	−0.0270*	−0.0322**	−0.0329**	−0.0328**
	(0.0277)	(0.0277)	(0.0156)	(0.0157)	(0.0155)	(0.0155)	(0.0155)
Lag log violation		0.0148**	0.0124**	0.0127**	0.0123**	0.0129**	0.0129**
		(0.00684)	(0.00539)	(0.00542)	(0.00536)	(0.00544)	(0.00546)
Lag log water revenue			0.453***	0.441***	0.405***	0.410***	0.410***
			(0.0515)	(0.0525)	(0.0538)	(0.0524)	(0.0524)
Lag log debt out'				0.0378***	0.0288***	0.0282***	0.0283***
				(0.00772)	(0.00690)	(0.00681)	(0.00681)
Lag log property tax					0.115***	0.138***	0.138***
					(0.0250)	(0.0309)	(0.0307)
Lag log population						−0.0388**	−0.0385**
						(0.0169)	(0.0168)
Total insurance frac						0.00363	0.00308
						(0.0184)	(0.0181)
Moody rating							0.000910
							(0.00109)
Is rated by Moody							-0.0173
							(0.0204)
Observations	27,505	27,505	27,505	27,505	27,505	27,469	27,469
County FE	YES	YES	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES	YES	YES

Robust standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 7: Effects of Bond Insurer Downgrades on Drinking Water Pollution

This table presents OLS regression estimates of the effects of bond insurer credit rating downgrades on drinking water pollution. The dependent variable is the logarithm of the number of violations of federal health standards for drinking water observed in a municipality in a given year. The key independent variable of interest is *Treatment*: an interaction term between whether a given observation is taken in 2007 or afterwards, and whether a given municipality has a high or low (i.e. above- or below- the 2006 sample median) fraction of outstanding debt that is insured by downgraded monoline companies. Controls are described in Table A1. The sample period is from 1980-2019. Standard errors are clustered at the municipality and year level.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Treatment	0.0728**	0.0610**	0.0610**	0.0610**	0.0600**	0.0588**	0.0586**
	(0.0333)	(0.0270)	(0.0270)	(0.0270)	(0.0270)	(0.0270)	(0.0270)
Lag log violation		0.244***	0.244***	0.244***	0.244***	0.243***	0.243***
		(0.0258)	(0.0257)	(0.0257)	(0.0256)	(0.0255)	(0.0255)
Lag log water revenue			0.00271	0.00440	−0.00268	−0.00384	−0.00387
			(0.0165)	(0.0164)	(0.0168)	(0.0172)	(0.0172)
Lag log debt out'				−0.00509	−0.00693	−0.00818	−0.00865
				(0.00868)	(0.00869)	(0.00867)	(0.00861)
Lag log property tax					0.0242	0.0159	0.0175
					(0.0162)	(0.0224)	(0.0229)
Lag log population						0.0137	0.0126
						(0.0212)	(0.0215)
Total insurance frac						0.0273	0.0293
						(0.0238)	(0.0241)
Moody rating							−0.00216
							(0.00270)
Is rated by Moody							0.0517
							(0.0517)
Observations	30,543	30,543	30,543	30,543	30,543	30,506	30,506
County FE	YES	YES	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES	YES	YES

Robust standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 8: Effects of Bond Insurer Downgrades on Drinking Water Revenue

This table presents OLS regression estimates of the effects of bond insurer credit rating downgrades on the drinking revenues earned by municipalities. The dependent variable is the logarithm of the total drinking water service fees earned by a municipality in a given year. The key independent variable of interest is *Treatment*: an interaction term between whether a given observation is taken in 2007 or afterwards, and whether a given municipality has a high or low (i.e. above- or below- the 2006 sample median) fraction of outstanding debt that is insured by downgraded monoline companies. Controls are described in Table A1. The sample period is from 1980-2014. Standard errors are clustered at the municipality and year level.

	(1)	(2)	(3)	(4)	(5)	(6)
Treatment	−0.0104	−0.0112	−0.00979	−0.0180	−0.0183	−0.0184
	(0.0282)	(0.0283)	(0.0271)	(0.0248)	(0.0250)	(0.0250)
Lag log violation		0.0173**	0.0178**	0.0156**	0.0151**	0.0150**
		(0.00808)	(0.00762)	(0.00713)	(0.00709)	(0.00714)
Lag log debt out'			0.112***	0.0840***	0.0852***	0.0849***
			(0.0113)	(0.00913)	(0.00948)	(0.00943)
Lag log property tax				0.250***	0.234***	0.235***
				(0.0349)	(0.0387)	(0.0385)
Lag log population					0.0243	0.0237
					(0.0311)	(0.0309)
Total insurance frac					−0.000181	0.00113
					(0.0233)	(0.0231)
Moody rating						-0.00256
						(0.00228)
Is rated by Moody						0.0478
						(0.0438)
Observations	25,279	25,279	25,279	25,279	25,244	25,244
County FE	YES	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES	YES

Robust standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 9: Effects of Bond Insurer Downgrades on Population Growth and Property Tax

This table presents OLS regression estimates of the effects of bond insurer credit rating downgrades on municipal population growth (Panel A) and on the total property tax revenue earned by municipalities (Panel B). The dependent variable is the logarithm of the total population of a municipality in a given year. The key independent variable of interest is $Treatment$: an interaction term between whether a given observation is taken in 2007 or afterwards, and whether a given municipality has a high or low (i.e. above- or below- the 2006 sample median) fraction of outstanding debt that is insured by downgraded monoline companies. Controls are described in Table A1. The sample period is from 1980-2019. Standard errors are clustered at the municipality and year level.

Panel A: Population Growth						
	(1)	(2)	(3)	(4)	(5)	(6)
Treatment	0.0245	0.0239	0.0282	0.0284	0.0164	0.0161
	(0.0243)	(0.0242)	(0.0229)	(0.0226)	(0.0204)	(0.0202)
Lag log violation		0.0123	0.0110	0.0114	0.0106	0.00980
		(0.00802)	(0.00726)	(0.00727)	(0.00667)	(0.00658)
Lag log water revenue			0.192***	0.178***	0.0658***	0.0655***
			(0.0343)	(0.0336)	(0.0227)	(0.0226)
Lag log debt out'				0.0411***	0.0176	0.0165
				(0.00989)	(0.0109)	(0.0109)
Lag log property tax					0.355***	0.358***
					(0.0639)	(0.0642)
Total insurance frac					−0.0766***	−0.0706**
					(0.0278)	(0.0268)
Moody rating						-0.00212
						(0.00160)
Is rated by Moody						0.0932***
						(0.0333)
Observations	28,272	28,272	28,272	28,272	28,237	28,237
County E	YES	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES	YES

Panel B: Property Tax Revenues						
	(1)	(2)	(3)	(4)	(5)	(6)
Treatment	0.0360	0.0359	0.0422	0.0425	0.0350	0.0354
	(0.0308)	(0.0307)	(0.0276)	(0.0270)	(0.0252)	(0.0249)
Lag log violation		0.00333	0.00155	0.00220	−0.00188	−0.000960
		(0.00716)	(0.00647)	(0.00620)	(0.00587)	(0.00586)
Lag log water revenue			0.278***	0.250***	0.170***	0.169***
			(0.0369)	(0.0331)	(0.0263)	(0.0258)
Lag log debt out'				0.0823***	0.0760***	0.0772***
				(0.0110)	(0.0104)	(0.0103)
Lag log population					0.252***	0.253***

					(0.0536)	(0.0535)
Total insurance frac					0.0260	0.0185
					(0.0247)	(0.0243)
Moody rating						0.00502**
						(0.00215)
Is rated by Moody						-0.146***
						(0.0404)
Observations	28,272	28,272	28,272	28,272	28,237	28,237
County FE	YES	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES	YES

Robust standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 10: Effects of Bond Insurer Downgrades on Municipal General Obligation Bonds

This table presents OLS regression estimates of the effects of bond insurer credit rating downgrades on the yields and amounts of general obligation bonds offered by municipalities. The dependent variable in Panel A is the weighted average yield of general obligation bonds offered by a municipality in a given year (where the weights are the bond amounts). The dependent variable in Panel B is the logarithm of the total amount of general obligation bonds offered by a municipality in a given year. The key independent variable of interest is *Treatment*: an interaction term between whether a given observation is taken in 2007 or afterwards, and whether a given municipality has a high or low (i.e. above- or below- the 2006 sample median) fraction of outstanding debt that is insured by downgraded monoline companies. Controls are described in Table A1. The sample period is from 1980-2019. Standard errors are clustered at the municipality and year level.

Panel A: Yield (in %) for general obligation bonds

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Treatment	0.119	0.117	0.118	0.117	0.117	0.121	0.121
	(0.0843)	(0.0843)	(0.0842)	(0.0843)	(0.0848)	(0.0836)	(0.0834)
Maturity	0.102***	0.103***	0.103***	0.103***	0.104***	0.0943***	0.0947***
	(0.0194)	(0.0194)	(0.0194)	(0.0194)	(0.0192)	(0.0192)	(0.0192)
Debt issuance	−0.329***	−0.329***	−0.327***	−0.326***	−0.325***	−0.325***	-0.321***
	(0.0497)	(0.0496)	(0.0499)	(0.0497)	(0.0501)	(0.0494)	(0.0496)
Lag log violation		0.0177	0.0187	0.0152	0.0150	0.0150	0.0156
		(0.0199)	(0.0200)	(0.0193)	(0.0192)	(0.0187)	(0.0187)
Lag log water revenue			−0.101*	−0.0835*	−0.0592	−0.0634	−0.0636
			(0.0505)	(0.0477)	(0.0448)	(0.0451)	(0.0444)
Lag log debt out'				−0.0761*	−0.0689	−0.0880*	−0.0881**
				(0.0448)	(0.0428)	(0.0429)	(0.0430)
Lag log property tax					−0.0699	−0.0663	−0.0683
					(0.0613)	(0.0758)	(0.0760)
Lag log population						0.00410	0.00586
						(0.0622)	(0.0621)
Total insurance frac						0.366***	0.363***
						(0.113)	(0.112)
Moody rating							−0.000796
							(0.00537)
Is rated by Moody							-0.0429
							(0.0994)
Observations	5,679	5,679	5,679	5,679	5,679	5,679	5,679
County FE	YES	YES	YES	YES	YES	YES	YES

Year FE	YES	YES	YES	YES	YES	YES	YES

Panel B: General obligation debt flow

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Treatment	0.00961	0.00975	0.00976	0.0112	0.0115	0.0108	0.00902
	(0.0122)	(0.0122)	(0.0121)	(0.0121)	(0.0121)	(0.0122)	(0.0124)
Lag log go debt out'	0.936***	0.936***	0.936***	0.928***	0.928***	0.928***	0.926***
	(0.00774)	(0.00773)	(0.00776)	(0.00866)	(0.00866)	(0.00857)	(0.00863)
Lag log violation		−0.00336	−0.00336	−0.00363	−0.00360	−0.00339	−0.00454
		(0.00358)	(0.00356)	(0.00355)	(0.00356)	(0.00358)	(0.00365)
Lag log water revenue			0.000378	−0.00390	0.000837	0.00333	0.00391
			(0.00755)	(0.00765)	(0.00772)	(0.00782)	(0.00792)
Lag log debt out'				0.0187**	0.0198***	0.0185**	0.0173**
				(0.00719)	(0.00713)	(0.00758)	(0.00750)
Lag log property tax					−0.0152*	−0.00666	0.000186
					(0.00783)	(0.00914)	(0.00910)
Lag log population						−0.0144**	−0.0197**
						(0.00712)	(0.00738)
Total insurance frac						−0.00367	0.00556
						(0.0202)	(0.0193)
Moody rating							−0.00158
							(0.00172)
Is rated by Moody							0.122***
							(0.0298)
Observations	20,678	20,678	20,678	20,678	20,678	20,659	20,659
County FE	YES	YES	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES	YES	YES

Robust standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 11: Mechanism: Signalling Benefits of Bond Insurance

This table contains regression estimates for our main specifications, across sample municipalities distinguished by their per capita property tax revenues. Panel A (Panel B) consists of observations for municipalities with per capita tax revenues above (below) sample-median figures. The dependent and independent variables correspond to the fully saturated specifications presented in Tables 3 through 7. Controls are described in Table A1. The sample period is from 1980-2019. Standard errors are clustered at the municipality and year level.

Panel A: High quality: Above-median per-capita property tax					
	Borrowing costs	Financing expenses	Borrowing amounts	Municipal investments	Water pollution
Treatment	0.00241***	0.118***	-0.0321**	-0.0409*	0.0773**
	(0.000792)	(0.0403)	(0.0149)	(0.0223)	(0.0376)
Observations	5,643	6,830	15,650	15,306	17,550
County FE	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES
Controls	YES	YES	YES	YES	YES

Panel B: Low quality: Below-median per-capita property tax					
	Borrowing costs	Financing expenses	Borrowing amounts	Municipal investments	Water pollution
Treatment	-0.0001	0.0771*	-0.0165	-0.0331	0.0328
	(0.00108)	(0.0413)	(0.0158)	(0.0210)	(0.0367)
Observations	3,859	4,748	11,877	12,126	12,918
County FE	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES
Controls	YES	YES	YES	YES	YES

Robust standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 12: Mechanism: Tax Exemption Benefits of Municipal Bond insurance

This table contains regression estimates for our main specifications, across sample municipal bonds distinguished by the lengths of time left until maturity. Panel A (Panel B) consists of observations for municipalities with debt outstanding with years below (above) sample-median years to maturity. The dependent and independent variables correspond to the fully saturated specifications presented in Tables 3 through 7. Controls are described in Table A1. The sample period is from 1980-2019. Standard errors are clustered at the municipality and year level.

	(1)	(2)	(3)	(4)	(5)
Panel A: Low tax benefit: Below-median years to maturity					
	Borrowing costs	Financing expenses	Borrowing amounts	Municipal investments	Water pollution
Treatment	0.00181*	0.0327	-0.0597***	-0.0257	0.0903**
	(0.000968)	(0.0481)	(0.0170)	(0.0208)	(0.0349)
Observations	3,624	4,914	13,254	13,377	14,964
County FE	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES
Controls	YES	YES	YES	YES	YES
Panel B: High tax benefit: Above-median years to maturity					
	Borrowing costs	Financing expenses	Borrowing amounts	Municipal investments	Water pollution
Treatment	0.00131	0.125***	0.00290	-0.0440*	0.0267
	(0.000784)	(0.0398)	(0.0142)	(0.0220)	(0.0365)
Observations	5,889	6,675	14,312	14,092	15,542
County FE	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES
Controls	YES	YES	YES	YES	YES

Robust standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Appendix

In this section, we provide a detailed description of the dataset construction.

We first obtain data from the U.S. Census Annual Survey of State and Local Government Finances from 1980 to 2019. These data are publicly available online at: https://www.census.gov/programs-surveys/gov-finances.html. As described on the Census website, this survey provides comprehensive information on the finances and investment activities of local governments across the U.S. For example, the data contain information on the assets, revenues, and expenditures of local governments across specific functions such as water supply, utilities, transit, etc. The Census survey is conducted annually, and corresponds to a large, randomized sample of local municipalities. Additionally, every five years (i.e. years ending in '2' and '7'), the Census gathers data for the entire population of local municipalities in the U.S.

The key variables that we use to extract information from the Census Surveys are described in Table A1. For example, "Water Utility" is the Census governmental unit that corresponds to drinking water infrastructure: the Census defines this entity as being "responsible for the operation and maintenance of water supply systems...to the general public". Table A1 describes other variables that we collect from the Census, such as measures of drinking water revenues, investment expenditures into drinking water infrastructure, property tax revenues, etc.

We supplement these data with information on the credit ratings of municipalities. Specifically, we obtain detailed time-series data on the credit ratings (by Moody's) of municipal entities from Eikon. We codify the credit ratings (such as Aaa, Aa1, etc.) numerically by assigning each credit rating a value, such that Aaa=21, Aa1=20...C=1, following Cornaggia et al. (2018). If a municipality does not have a credit rating, we leave this value as 'missing'.

Second, we collect detailed information on municipal debt issues from SDC Platinum's Global Public Finance database. These data contain records for every individual debt offering made by U.S. municipal entities from 1962 to 2019. For each debt issue, we observe the total amount of capital raised, the debt's maturity, debt type (revenue bond or general obligation bond), and the stated purpose of the debt issue (for example: water infrastructure). SDC also provides information on bond yields, which we use to construct measures of borrowing costs (see "Yield" in Table A1 for an explanation).

In addition to these data, SDC contains information about whether an individual bond issue is insured, and if so, the identity of the insurance company that is backing the debt. For each bond insurance company in our sample, we obtain its credit ratings history from S&P Capital IQ, and cross-check these data with other studies such as Bergstresser et al. (2010) and Cornaggia et al. (2020a). These data enable us to precisely identify changes in bond insurers' financial health.

We use these data to construct a detailed time-series of debt used to finance public drinking water infrastructure for each municipality in our sample. The vast majority ($> 95\%$) of debt issues are fixed rate, fully amortized securities; we use full amortization schedules to construct estimates of the total municipal debt outstanding each year, based on observed prior history of debt issuances for each municipality. We construct these measures for all insured and uninsured debt, and compute the total amount of a municipality's debt outstanding that insured by each bond insurance company in our sample. v

Finally, we collect data on public drinking water quality from the U.S. Environmental Protection Agency (EPA). The EPA maintains a database called the Safe Drinking Water Information System (SDWIS), which contains information on public water systems throughout the U.S., as required by the 1974 Safe Drinking Water Act (SDWA). The database is publicly available at https://www.epa.gov/ground-water-and-drinking-water/safe-drinking-water-information-system-sdwis-federal-reporting.

The database contains records of federal violations of drinking water standards by public water systems. These standards are set by the SDWA, and apply equally across all local jurisdictions in the U.S. The SDWIS contains detailed information about the types of violations observed by local water systems, such as instances of contaminant levels that exceed the limits set forth by the SDWA. The database also maintains records of violations of federally approved water treatment techniques and reporting requirements.

We use the SDWIS data to measure changes in drinking water quality across municipalities in our sample. The individual records in the SDWIS are uniquely identified by individual violations of specific SDWA rules committed by public drinking water systems each year. The database identifies whether individual violations have health-based implications (for example, whether there are high levels of lead or bacteria in a water system), or whether the violations are unrelated to health (such as whether the water system failed to submit water testing results on time to monitoring agencies).

There are typically multiple public drinking water systems that serve all the constituents of a given county. The database lists the county served by a given drinking water system, along with the number of people that are served by the system. To construct county-level measures of drinking water violations, we aggregate the observed health-related violations of all public drinking water systems in a given municipality, by year. We also weight these figures by the sizes of the populations served by these systems, to approximate the number of people affected by these violations.

We combine information from these different data sources into a single dataset, by aggregating the Census and SDC data to the county-year level (a county is the most disaggregated geographical unit for which we are able to observe changes in drinking water quality from the SDWIS, and both the Census and SDC list the county associated with a municipal entity in each data source). For example, the Census lists the county in which each individual municipal government belongs. We thus aggregate data on quantities such as municipal revenues and capital expenditures each year across all municipal governments within a given county. Similarly, SDC provides information on the county to which each municipal debt issuer belongs; we thus aggregate data on total debt raised and total outstanding debt (insured and uninsured) across municipalities to the county-level each year.

Aggregating and merging these data yield a panel dataset that consists of observations at the county-year level from 1980 to 2019. Each record contains information on annual drinking water revenues and investments into drinking water infrastructure. In each record, we also observe the total amount of municipal debt outstanding (insured and uninsured) raised for water infrastructure up to a given year. Each observation also contains information on federal violations of drinking water standards recorded for community water systems in a given county-year.

Table A1: Variable Definitions

Source: U.S. Census of Government Finances	
Water utility	Entity responsible for the operation and maintenance of water supply systems including the acquisition and distribution of water to the general public or to other local governments for domestic or industrial use. The acquisition and distribution of water for irrigation of agricultural lands is excluded.
Water revenue	Revenue from sale of utility commodities and services to the public and to other governments. Does not include amounts from sales to the parent government. Also excludes income from utility fund investments and from other nonoperating properties. Excludes any monies from taxes, special assessments, and intergovernmental aid. Raw data are available at sub-county-year levels, and are aggregated to the municipality-year level.
Water interest expense	Amounts paid to service outstanding municipal debt that is issued specifically to finance city-owned and operated water utility facilities. Raw data are available at sub-county-year levels, and are aggregated to the municipality-year level.
Water investment	Includes maintenance expenditure for works and structures related to drinking water infrastructure. Includes direct expenditure for compensation of officers and employees and for supplies, materials, and contractual services. Raw data are available at sub-county-year levels, and are aggregated to the municipality-year level.
Population	Number of residents. Raw data are available at sub-county-year levels, and are aggregated to the municipality-year level.
Property tax	Taxes conditioned on ownership of property and measured by its value. Includes general property taxes related to property as a whole, real and personal, tangible or intangible, whether taxed as a single rate or at classified rates, and taxes on selected types of property, such as motor vehicles or certain or all intangibles. Raw data are available at sub-county-year levels, and are aggregated to the municipality-year level.
Intergovernmental revenue: Federal	Intergovernmental revenue received by the government directly from the Federal Government. Excludes Federal aid channeled through state governments. Raw data are available at sub-county-year levels, and are aggregated to the municipality-year level.
Intergovernmental revenue: State	All intergovernmental revenue received from the state government, including amounts originally from the Federal Government but channeled through the state. Raw data are available at sub-county-year levels, and are aggregated to the municipality-year level.
Intergovernmental revenue: Local	Fiscal aid revenue that allows the receiving government unrestricted use as to function or purpose. Raw data are available at sub-county-year levels, and are aggregated to the municipality-year level.

Source: SDC Platinum	
New Debt issuance	Sum of par amounts of related issues considered a single issue by the issuer. Purposes are given by SDC Platinum or inferred by the name of the issuing entity. Raw data are available at sub-county-year levels, and are aggregated to the municipality-year level.
Insured amount of new debt issuance	Total par amount insured. For one or more bond insurers, the insured amount of debt is the total par amount of the insured tranches. Raw data are available at sub-county-year levels, and are aggregated to the municipality-year level.
Total debt outstanding	We use full amortization schedules to construct estimates of total debt outstanding based on historical debt issues, maturities, and coupon rates.
Total debt insured	We use full amortization schedules to construct estimates of total insured debt outstanding based on historical debt issues, maturities, and coupon rates.
True interest cost	SDC-defined measure defined as the rate, compounded semi-annually, necessary to discount the amounts payable on the respective principal and interest payment dates to equal the purchase price received for the new debt issuance. Raw data are available at sub-county-year levels, and are aggregated to the municipality-year level.
Yield of final maturity	SDC-defined measure: The yield or the price of ending serial maturities in ranges of serial maturities. Raw data are available at sub-county-year levels, and are aggregated to the municipality-year level.
Coupon of final maturity	SDC-provided measure: The coupon of the final term maturity or final serial maturity in the final range of serial maturities. Raw data are available at sub-county-year levels, and are aggregated to the municipality-year level.
Yield	This measure is constructed using the following procedure: Yield = "True interest cost" if this value is provided by SDC. If not, then Yield = "Yield of final maturity" if available. If this value is not available, Yield is calculated using the bond price if available, along with maturities and coupon rates. Finally, if these inputs are not available, Yield = "coupon of final maturity." Raw data are available sub-county levels. We aggregate them up to county-year level.
Source: U.S. EPA Safe Drinking Water Information System (SDWIS)	

SDWA violations (pop wgt)	The number of federal health-related violations of the U.S. Safe Drinking Water Act by public community water systems (weighted by the population served by the community water system, where indicated). We observe three types of violations: maximum contaminant level violations, maximum residual disinfectant level violations, and water treatment technique violations. Raw data are available at sub-county-year levels; data are aggregated to the municipality-year level.
Source: Refinitive Eikon	
Issuer rating	Issuer's credit rating assigned by Moody's. Raw data are available at sub-county-year levels; data are aggregated to the municipality-year level.